IMPROVING COGNITIVE INDEPENDENCE OF DEMENTIA PATIENTS USING MACHINE LEARNING ENABLED MOBILE APPLICATION

Project Id: 2023-081

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B.Sc. (Hons) Degree in Information Technology

(Specialization in Data Science)

Department of Data Science

Sri Lanka Institute of Information Technology

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The dissertation was submitted in partial fulfilment of the requirements for the B.Sc. Special Honors degree in Information Technology (Specialization in Data Science)

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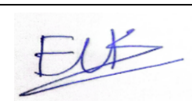
DECLARATION

We declare that this is our work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any otheruniversity or institute of higher learning, and to the best of our knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Name	Student ID	Signature
Kachchakaduwa E.U.	IT20230388	

The above candidates are researching the undergraduate Dissertation under mysupervision.

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Signature of co-supervisor: Date:

ABSTRACT

Dementia is the loss of cognitive functioning such as thinking, remembering, reasoning and decision-making that interrupts a person's daily activities. This occurs because of the damage that happens to the brain cells which interferes with the communication of that person that affects thinking, behaviors and feelings. Most Dementia patients have got wandering as one of their major concerning habits, where they may leave their home or the place, they should be without informing or notifying others. Since Dementia patients are frequently suffering from short-term memory impairment, this can lead to a dangerous accident for the patient. Also, with the busy workloads that caregivers or family members have due to the current complex society, they might not be able to keep their focus on the Dementia patient all the time. By frequently using living activities, caregivers are encouraged to help the patients, but they need to promote their self-independence at the same time. Then most Dementia patients have a habit of notifying themselves about the current date, time, and weather conditions. Although there are tracking mechanisms around the world, there are few location tracking systems available which have been specified only for Dementia patients but most of them are not user-friendly and vulnerable in certain situations.

Therefore, an innovative, user-friendly, smart solution is needed. The IoT can provide a reliable, sustainable, and fully functional solution for these problems by using sensors to monitor the movement and track the location of patients [1]. By using interconnected sensing technology, the possibility is there to solve the above-mentioned two major problems that happen with their habits. This device provides benefits for both parties, patients, and caregivers by facilitating the caregivers to predefine the safe zones according to their whereabouts and track down the movement of the patient by using sensors and trackers. If the patient goes out of those defined safe zones, caregivers are notified in real time and can call the patients via the device to prevent any dangers. As an additional feature, by using ML, this device keeps historical records about the places the patients have visited so it can analyze and understand to predict the patient's habits to help the caregiver take necessary action for the care and safety of the patient.

Keywords - Dementia, wandering, memory impairment, Internet of Things, sensors.

ACKNOWLEDGEMENT

First and foremost, I want to express my heartfelt gratitude to my supervisor, Mrs. Geethanjali Wimalaratne, for all of her encouragement, advice, and support during the study process, as well as the insightful observations he made to aid the research project to flourish. Aside from my supervisor, I'd like to thank Ms. Wishalya Tissera, the study project's co-supervisor, for always being willing to help. Many people worked hard to complete this research. Their excellent expertise and time assisted me in reaching ideal results during the course of my educational endeavour. In addition, I'd like to thank the CDAP team for their assistance in finishing our project effectively. Next, I would like to thank our external supervisor, Mrs. Surangi Somaratne, head of the Neurology department of Kamburugamuwa National Hospital, Matara for providing valuable insights and helping our project's success in so many ways. Then, I'd like to express my heartfelt appreciation to my friends for their unfailing support during this endeavour. In addition, I'd want to express my gratitude to my parents for their constant support and encouragement. A special thanks to the other researchers who collaborated with me to make this research more effective and successful.

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LIST OF ABBREVIATIONS

Abbreviation	Description
IoT	Internet of Things
ML	Machine Learning
WSD	Wearable Sensing Devices
WHO	World Health Organization
RAM	Remote Activity/Alarm Monitoring
WBS	Work Breakdown Structure
GPS	Global Positioning System
SIM	Subscriber Identity Module
IMEI	International Mobile Equipment Identity
API	Application Programming Interface
RFID	Radio Frequency Identification
LSTM	Long-Short Term Memory
RNN	Recurrent Neural Network
MAE	Mean Absolute Error
MSE	Mean Squared Error
NaN	Not a Number

1. INTRODUCTION

1.1 Background and Literature Survey

Dementia exerts its most profound impact on the brain's memory-controlling cells, leading to a distressing phenomenon known as wandering among affected individuals [2]. This behavior is characterized by a compulsion to move about without a specific destination or clear sense of direction. For those grappling with memory impairment, the urge to walk aimlessly becomes a manifestation of their cognitive challenges.

Wandering in dementia can be triggered by a complex interplay of emotional and physical factors. Emotional drivers often include stress, fear, overstimulation, and frustration, which can prompt individuals to seek solace in movement. On the other hand, physical causes encompass poor dimension perception, visual-spatial problems, impaired eyesight, and limited mobility. In nighttime hours, factors such as boredom, perceived obligations, physical discomfort, and temperature extremes (feeling too hot or too cold) can contribute to the same wandering behavior [3].

This study delves into the pervasive issue of wandering in dementia and its profound effects on both patients and their devoted caregivers. Previous research findings have underscored the severity of the problem, revealing that dementia-related wandering is far more consequential than commonly perceived. Astonishingly, the Alzheimer's Association reports that approximately 60% of individuals with dementia experience wandering at some point during the disease [4]. What makes wandering particularly perplexing is its unpredictability [5].

The enigmatic nature of wandering poses a significant challenge for caregivers and healthcare providers alike. Understanding the multifaceted causes and emotional triggers behind this behavior is essential in developing effective strategies and interventions to enhance the safety and well-being of dementia patients. Moreover, the prevalence of wandering highlights the urgent need for innovative solutions and comprehensive support systems to address this critical aspect of dementia care.

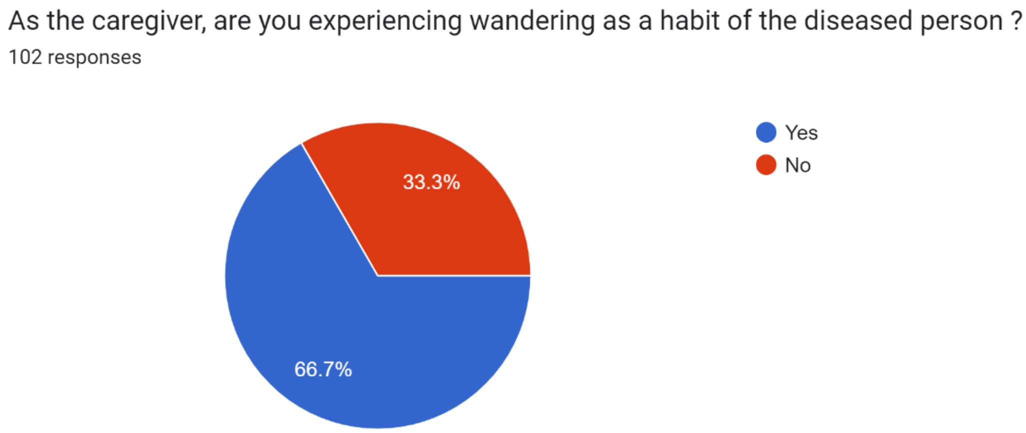

Figure 1.1. 1: Survey results on the frequency of wandering as a habit of dementia patients

The number of people that are diseased with dementia is rising today at a larger scale. Since the beginning of 2020 due to Covid-19, people were forced to stay at their homes and elderly people who are living lonely have been affected by this to be victims of mental illnesses. Dementia has become the most common illness among them [6]. At the same time, studies show that people who were dealing with dementia morbidity and mortality from Covid-19 [7]. Although currently, people are living in post-pandemic, for elderly people it has become hard to adapt to the era of new normalization. So, in the post-pandemic, they tend to travel a lot but with short-term memory impairment, the risk of wandering is high, and this can be highly hazardous. Then caregivers need to pay more attention and put more focus towards the patients than ever before.

WSD and IoT have been identified as two of the most evolving and emerging technologies, they can be used to revolutionize the existing solutions for the wandering problem of dementia patients. Since the beginning of Covid – 19 pandemics, monitoring patients remotely has evolved significantly and it has become synonymous with the health industry with the introduction of Mobile Health [8]. With the growth of user acceptance of smartwatches for medical purposes, the general public’s motive towards using technology is to reduce the complexity of their lives [9]. With the implementation of the sensors, identification of the patterns of movements of a patient can be done up to a certain extent so a behaviour out of the ordinary could be detected, identified, and reported on. It is also important to maintain bidirectional communication between the patient and the caregiver since it helps to keep the mental stability of the patients, but it is an extra burden for caregivers [10].

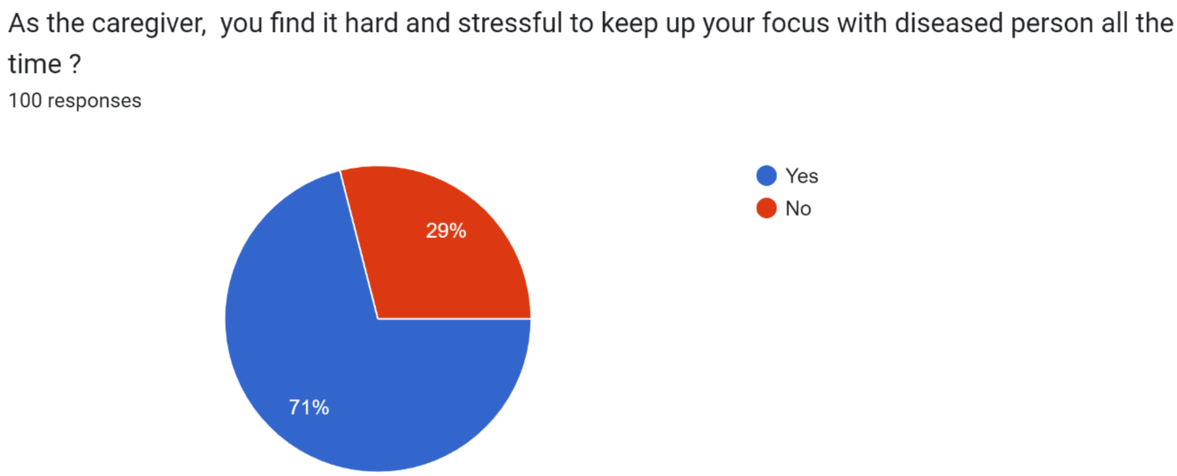

Figure 1.1. 2: Survey results on the stressful nature and the burden on caregivers of dementia patients

1.2 Research Gap

When considering the whole system, there is a very limited number of devices and tools which have been implemented to assist Dementia patients, but the wandering problem has not been addressed by most of them. Also, they lack certain key functionalities and some of them are highly outdated. Because of this, caregivers search for new technical solutions which are current and futuristic. Most existing options have not been built to establish safe zones facility for caregivers which can massively impact the well-being of the patient and minimize the burden on caregivers' shoulders.

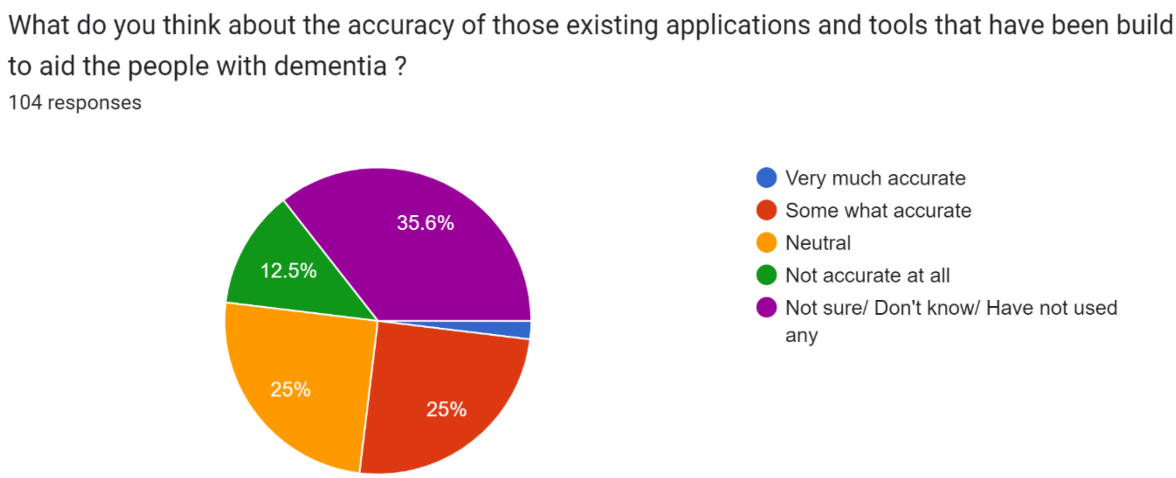

Figure 1.2. 1: Survey results on user experience and satisfaction with existing applications and tools

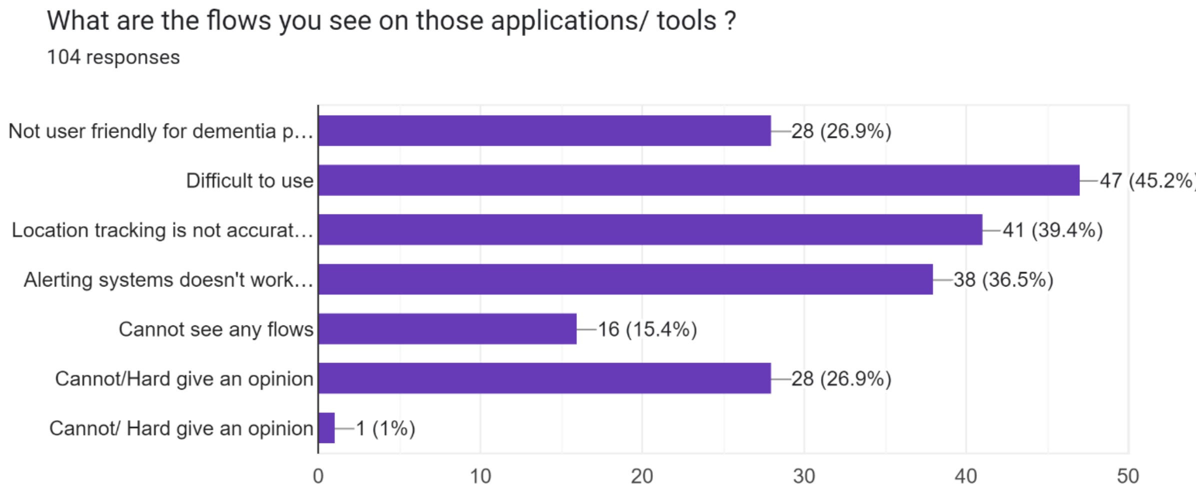

Figure 1.2. 2: Users' ideology about existing tools and their flows/ what areas mainly need to address.

Although there are some research has been done regarding the wandering problem of dementia patients, certain implementations cannot be found in the real world [11]. Research A [12] paper explains assistive mobile health applications and wearable IoT devices have been developed for patients who are in the early stages of Alzheimer's disease (which is a diagnosis of dementia) to maintain their mental activeness. Research B [11] paper explores the movement and location tracking mechanism that has been built for dementia patients. Research C [13] (Real-time Location Tracker for Critical Health Patient using Arduino, GPS Neo6m and GSM Sim800L in Health Care) paper describes the real-time location tracking system which has been built using sensors, google maps and tools such as Arduino boards.

Table 1.2. 1: Research gap by comparing the proposed system with existing systems.

	Research A	Research B	Research C	Proposed system
Track the current location of the patient and monitor movement and speed constantly	✗	✓	✓	✓
Establish safe zones and change them	✗	✗	✗	✓

according to the whereabouts at the time by caregivers				
Analyze patient’s historical records and predict future movements	×	×	×	✓
Alarming & alerting system for emergencies	×	✓	×	✓

As of now, there exists no research or application that harnesses the wealth of data within a patient's historical records of frequently visited places to analyze and predict their future movements, thereby mitigating and preventing potential disasters. Considering this research gap, we propose the development of an innovative mobile application that seamlessly integrates with a location tracking device. This application is envisioned to offer a comprehensive solution, addressing the critical need for predictive capabilities in dementia care.

The core concept underlying this groundbreaking application is the utilization of a patient's historical location data. By collecting and analyzing data on places the patient has visited frequently, we can uncover valuable insights into their behavioral patterns and preferences. This, in turn, forms the foundation for predicting the patient's future movements with a high degree of accuracy.

The key functionalities of this proposed mobile application include real-time location tracking and analysis, intelligent predictive algorithms, and customizable safe zones. Patients would wear a location tracking device that communicates with the mobile app, continually updating the patient's whereabouts. The app would then employ advanced algorithms to identify patterns and trends in the patient's movements, using the historical data as a reference.

The predictive capabilities of this application hold immense promise. Caregivers and healthcare professionals would be alerted when a patient deviates from their expected routine or enters potentially hazardous areas. This proactive approach has the potential to prevent accidents, injuries, and even fatalities.

Moreover, the application aims to provide patients with a degree of independence while ensuring their safety. Carefully defined safe zones can be configured, allowing patients to move within these boundaries without triggering alarms. This balance between independence and safety fosters a sense of autonomy for dementia patients.

In summary, the proposed mobile application represents a significant leap forward in dementia care. By harnessing the untapped potential of historical location data, it offers the means to predict patient movements, minimize risks, and enhance the quality of life for both patients and caregivers. This innovative solution has the potential to bridge the existing research gap and make a profound impact on dementia care, ensuring a safer and more dignified life for those affected by this condition.

1.3 Research Problem

The public does not consider wandering as a major concern but when it comes to Dementia, it can be considered one of the most complex, dangerous, and challenging behaviors that can cause elopement, being lost, fatal injuries or even death at certain times. Inability to memorize all the activities and places that patients visit due to partial memory impairment highly impacts this. As shown in figure 1.5.1, the fatality rate among dementia patients is high. In figure 1.5.2, some users have shared their experiences and clearly, it shows that the patients were so close to their death. Certain studies and estimations suggest about 50% of dementia patients who wander either suffer from serious injuries or die unless they were not found within the next 24 hours.

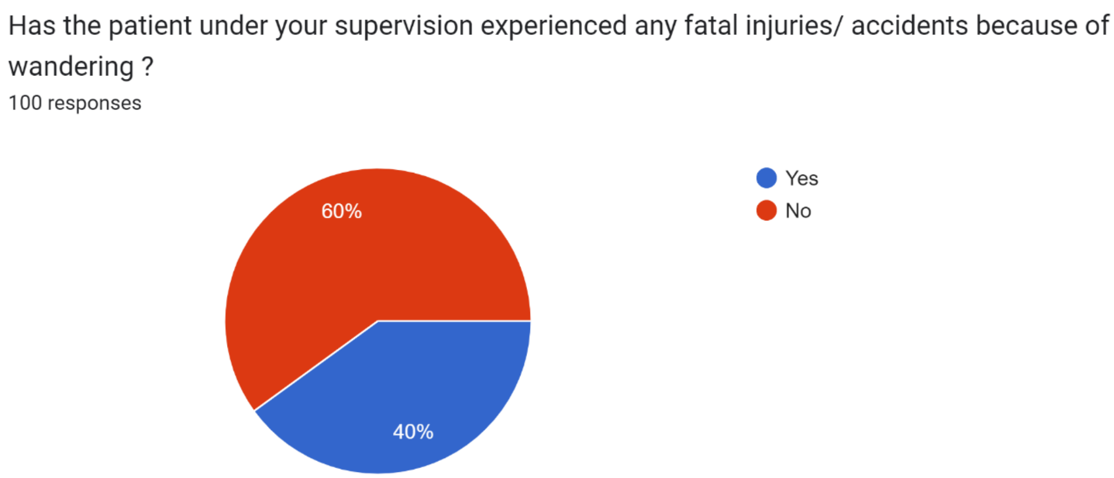

Figure 1.3. 1: Survey results on fatal injuries/ accidents that have happened because of wandering

If the answer is "Yes", please explain that experience.

18 responses

Wounded by a street dog while wandering

Once the patient was at a car crash site and he has been at the middle of the road.

Once when we went to a forest my grand mother lost and we found her while she was sinking in a river.

About 6 months ago my grand father was lost for 12 hours and a neighbour found him wounded after falling down.

My mother bumped into a car while wandering

My mom was drawning on a pool.

My father nearly died when he was wandering at night. We could not find him for 24 hours.

My aunt was wandering at once she was attacked by a dog.

My mother was attacked by a street dog while wandering and wounded

Figure 1.3. 2: Some experiences shared on fatal injuries/accidents that have happened in detail

Figure 1.3. 3: Previous research results on the impact of wandering

Making ensuring dementia patients are safe can be a tiresome and challenging task from the perspective of the carer. Dementia patients require continual attention and monitoring to limit and avoid potentially harmful situations. Carers, however, frequently struggle to prioritize continual supervision due to their hurried and complicated circumstances. In this case, carers face a dilemma: should they confine the patients to a certain location to limit their mobility and reduce the risk of accidents? Despite the fact that this appears to be a reasonable approach, it has a variety of detrimental consequences for these people's health.

One of the primary and most noticeable impacts of confining dementia patients is the severe blow it deals to their independence. Dementia can already erode many aspects of a person's autonomy, and limiting their ability to move freely only exacerbates this loss of control over their lives. The sense of being confined can lead to frustration, confusion, and even emotional distress for the patient. They may feel trapped and powerless, which can further worsen their mental state and overall quality of life.

Furthermore, physical immobilization resulting from confinement can have detrimental effects on the patient's health. Prolonged periods of inactivity can lead to muscle atrophy, joint stiffness, and a decline in overall physical well-being. This, in turn, can increase the risk of other health issues and potentially accelerate the progression of dementia.

The WHO emphasizes the importance of governments setting realistic goals to improve the quality of life of dementia patients and raise public awareness of this devastating disease by 2025. These goals underscore the critical need for technical solutions that may successfully support this noble cause while also serving as a critical platform for treating the expanding global dementia pandemic. In order to achieve these goals, it is critical to investigate and adopt novel technological solutions that can dramatically improve the lives of dementia patients. These solutions should cover a broad range of topics, including healthcare and assistive technologies, as well as public awareness campaigns and data-driven tactics.

By embracing technical solutions and integrating them into comprehensive strategies, countries can make significant progress toward achieving the WHO's goals for dementia care and awareness by 2025. Such efforts are not only vital for the well-being of dementia patients and their caregivers but also for building a more compassionate and informed society.

RAM systems have emerged as promising solutions to support caregivers in their role of caring for patients, particularly those dealing with dementia. These systems have the potential to serve as invaluable aids for caregivers, offering a range of functionalities designed to enhance patient safety and ease the caregiving burden. However, it's important to note that existing tools in this domain have encountered certain limitations and flaws, with one notable issue being the occurrence of false alarms. These false alerts can lead to unnecessary stress and disruptions for both caregivers and patients.

Fortunately, recent qualitative research findings, as highlighted in a study [14], have shed light on critical factors that can significantly improve the effectiveness of RAM systems. These findings emphasize the importance of alert context, accuracy, and the specific type of alerting mechanisms employed. By refining these aspects of RAM systems, developers and healthcare professionals can work towards reducing false alarms and enhancing the overall utility of these tools.

The concept of creating safe zones inside a patient's living environment is one of the research's most notable findings. These safe zones can be designated strategically as regions where patients are anticipated to remain. The RAM system can automatically trigger an alert in the event of an emergency or if a patient leaves the defined safe zone. This novel strategy not only improves patient safety but also relieves carers of a large percentage of the caregiving tasks. It gives them piece of mind knowing that if their loved one gets into a potentially dangerous scenario, they will be contacted immediately.

Currently, there are no foolproof methods available to accurately predict a dementia patient's future movements by solely analyzing their past records. Nevertheless, the development of such predictive capabilities holds immense potential as a significant boon for caregivers. Studies have revealed that dementia patients often exhibit certain recurrent patterns when they wander or move about. If caregivers were equipped with the ability to anticipate these patterns, it could substantially reduce the stress and anxiety associated with caregiving.

The importance of this predictive feature cannot be overstated. With access to predictive analytics, caregivers could create a more relaxed and secure environment for both them and the dementia patients under their care. Knowing when and where a patient might wander allows caregivers to proactively address their needs and ensure their safety.

Moreover, this predictive capability has the potential to offer dementia patients a greater degree of independence while still being under supervision. Independence is a fundamental aspect of human dignity, and for dementia patients, it can significantly enhance their quality of life. The ability to move about within predetermined boundaries, confident that caregivers are aware of their whereabouts, fosters a sense of autonomy that can be invaluable to their emotional well-being.

Importantly, this predictive approach also has the potential to minimize the occurrence of fatal accidents and injuries among dementia patients. By identifying and responding to wandering patterns, caregivers can prevent patients from straying into hazardous situations, reducing the risk of accidents. Furthermore, this proactive approach could potentially avert untimely deaths that may otherwise occur among this vulnerable population.

In essence, the development of prediction capacities for the movements of dementia patients constitutes a game-changing improvement in dementia care. It has the potential to improve both patients' and carers' overall quality of life by lowering stress, boosting independence, and averting critical occurrences. As technology and research in this sector advance, the prospects for enhancing the lives of dementia patients and carers become more optimistic.

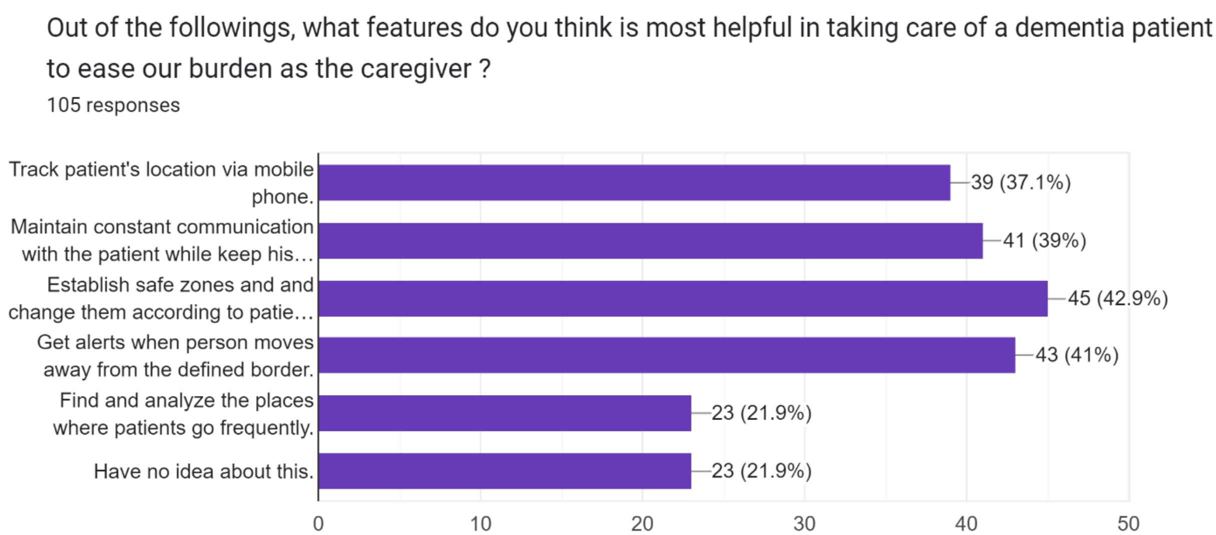

Figure 1.3. 4: Users' responses to the proposed features of the system via the survey

In this proposal is mainly addressing about the wandering behaviour of dementia patients with its impacts on both patients and caregivers, constant monitoring of the movement speed of patients, establishing safe zones and changing them according to the patient's current environment, bidirectional communication between the caregiver and the patient, analyze and predict patients future movements using historical records while fulfilling the wish of a dementia patient to know about current date, time, and the weather condition.

2. RESEARCH OBJECTIVES

2.1 Main Objective

The main objective of this research study is to provide a smart solution for the wandering behaviour of dementia patients by inventing a tracking mechanism to track locations while establishing safe zones and analyzing their movement patterns for future predictions.

2.2 Specific Objective

With the above-mentioned main objective, the following specific objectives are intended to be accomplished when it comes to the whole component and overall implementations.

To track patients' locations in real-time.

- The fundamental goal of managing the problem of wandering among dementia patients is to maintain constant awareness of the persons who are prone to wandering and the sites they frequent. This necessitates the incorporation of a dependable real-time location tracking system. While similar systems do exist in the real world, carers have expressed reservations about their accuracy and effectiveness. These concerns emerge from the important necessity for precision in assuring dementia patients' safety.
- Caregivers are entrusted with the difficult task of keeping constant tabs on dementia patients, particularly those who wander. The limits of conventional location monitoring methods, on the other hand, have encouraged the search for a more dependable and user-friendly alternative.
- The proposed location tracking device offers a robust solution by capturing and transmitting the real-time location of the patient. Caregivers can access this information conveniently through their mobile devices, allowing them to monitor the patient's movements with greater accuracy and peace of mind. This real-time tracking capability represents a significant advancement in the realm of dementia care, offering caregivers a valuable tool to enhance patient safety while alleviating some of the burdens associated with constant supervision.

To identify the established safe zones with customizable options while giving alerts to caregivers in emergencies

- It is required to have a suitable and matching method to establish boundaries in the virtual map while analyzing the real geographical locations. For this geofencing will be used since it has the most efficiency and reliability. Alerts will be triggered when patients cross those defined virtual boundaries. The option to customize those boundaries according to the place will be provided to the caregivers.

To build a predictive model to analyze patients' historic records and predict future movements.

- After gathering location-related data via the tracking device, the same can be used to predict future movements using ML techniques. Decision Tree and Random Forest algorithms will be used to generate predictions with high accuracy.

3. METHODOLOGY

3.1 Methodology

The primary goal of this research is to build and execute a comprehensive system aimed at improving dementia patients' cognitive independence through the integration of a machine learning-enabled mobile application. The specific role and contribution within the scope of this vast project focuses on in-depth research, exhaustive study, and meticulous analysis of the wandering behavior shown by dementia patients.

Understanding the complexities of dementia wandering is critical to the success of this program. A more detailed understanding can be acquired by looking into the behavioral patterns and underlying reasons of wandering. This extensive research serves as the foundation for developing an efficient and timely answer.

The ultimate objective is to provide caregivers and healthcare professionals with an innovative and efficient solution that mitigates the challenges posed by wandering behavior in dementia patients. This solution, rooted in the insights and findings derived from this dedicated research, seeks to empower patients and enhance their cognitive independence, thereby contributing to a higher quality of life for those affected by dementia.

The utilization of a tracking device for real-time location monitoring via a mobile phone represents a groundbreaking development that effectively alleviates a significant portion of the stress and burden borne by caregivers responsible for dementia patients. The constant need for vigilant supervision can be overwhelming, but this innovative solution offers a much-needed respite. Caregivers no longer have to maintain unwavering focus on their patients at all times, thanks to the real-time tracking capabilities afforded by the mobile device.

Furthermore, the capacity to create and modify safe zones based on the patient's current environment emerges as a significant benefit for both caregivers and patients. These safe zones are preset boundaries within which patients can move without generating alerts. Caregivers may customize these zones to their preferences and the individual needs of the patient, encouraging a sense of control and personalization in dementia care.

The device and mobile application are linked by a sim card and the IMEI number that comes with the device. IMEI numbers function similarly to bar codes and vary from device to device.

Location and movement tracking rely on modern sensors that are easily incorporated into the system. These sensors not only provide accurate real-time location data, but also provide information on the patient's movements. This multidimensional strategy improves carers' abilities to safeguard the safety and well-being of patients.

The entire system is designed to be accessible through user-friendly mobile applications, placing the power to define safe zones directly in the hands of caregivers. This convenience empowers caregivers to tailor the solution to the unique requirements of each patient and living environment, further reducing stress and enhancing the effectiveness of dementia care.

In essence, the inclusion of sensors and mobile applications into this system represents a watershed moment in dementia care. It not only relieves caregivers of the constant need for undivided attention, but it also offers them tools to make caregiving safer and more personalized. Finally, this comprehensive approach to dementia care strives to improve the quality of life for both patients and carers.

The tracking device was included as a result of a strategic relationship formed with Keygan Security Pvt Ltd. The VT03D is an innovative device that serves as a portable tracking solution, utilizing the power of a SIM card for activation and seamless interaction with the dedicated mobile application. This portable device is meant to track vehicles, but we have managed to convert that to track locations of humans. The device's commitment to protecting the privacy and security of each individual unit is a critical part of its design. This is accomplished by assigning unique IMEI numbers, which ensures differentiation and increases security.

VT03D incorporates a range of essential components, including microcontrollers, sensors, actuators, enclosures, displays, and batteries. In location tracking mechanisms, each of these features are playing a pivotal role in its robust functionality [15]. Microcontrollers serve as the backbone of the device, contributing significantly to its efficiency and overall functionality. Their presence ensures that this device as an efficient, well-functioning, and highly realistic location monitoring solution [15]. To capture actual real-time data, the device is equipped with sensors, a fundamental element that has proven to be highly effective in the realm of location tracking systems [16]. The inclusion of enclosures in the device design serves a dual purpose. Not only do they enhance the overall security of VT03D by providing physical protection for its internal components, but they also contribute to a reduction in development costs. Actuators are employed to facilitate the device's alerting and alarming functionality, ensuring that timely notifications can be issued in response to potential risks or emergencies. Given the device's intended use, batteries serve as the primary power source. This choice is driven by the necessity for VT03D to remain with patients for extended periods, necessitating a reliable and portable energy solution.

The inclusion of the Google Maps API, a powerful tool famous for its ability to offer real-time parameters and measures with outstanding precision [17], makes tracking patients' positions a breeze. Using this API's features ensures that the location monitoring system runs at the highest levels of precision and dependability.

To establish safe zones for patients, the system incorporates geofencing technology, a sophisticated approach that effectively creates virtual barriers corresponding to real-world geographical locations [18]. This feature allows caregivers to define specific areas within which patients can safely move. RFID is used to determine real world locations and trigger messages to the backend.

A key advantage of this system is the continuous and real-time monitoring of patients' locations and movements, affording caregivers the flexibility to stay informed whenever they choose. This level of access and insight into patient activity empowers caregivers to provide timely assistance and intervention when needed.

The device improves patient safety even more by triggering actions when patients leave or enter predetermined bounds. In reaction to these events, the system may automatically send warnings to authorized carers, ensuring that any deviations from the safe zones are communicated to them as soon as possible.

Importantly, even when patients venture outside the safe zones, their location continues to be actively monitored. Should they return to the safe zone before any adverse events occur, the system promptly notifies the caregivers overseeing the patients. This dynamic and proactive approach not only enhances patient safety but also provides caregivers with valuable reassurance, knowing that they will be alerted to any potential risks or incidents.

All the historical data regarding the places that the patients mostly visited or frequently visit, how many times he or she has crossed the defined safe zones, and patterns of movement will be stored within the system and after 4 months period, a new feature will be available for caregivers where the system is predicting the movement of the patients by analyzing and training those gathered data. A decision tree algorithm is a collection of simple decision rules that enable decision makers to make timely and suitable decisions about location prediction [19]. In the latest research, it has been found that random forest algorithms are more efficient and timely methods for location related predictions [20].

3.1.1. System Architecture

The suggested system would leverage React Native to create a user-friendly, intelligent, cross-platform mobile application that will maintain dementia patients' cognitive independence while relieving carers of a significant burden. The system is made up of four key components, which are mentioned below.

- Providing a smart solution by using voice recognition and NLP to maintain a digital audio diary by a patient as journalism helps to keep stability of memory
- Improving cognitive independence of dementia patients by directing them to the appropriate music therapy sessions while analyzing their emotional state
- Design a smart solution that has capability to detect patients loved ones and relatives via face recognition in a way that patient is fully independent.
- Providing a smart solution for wandering behavior of dementia patients by inventing a tracking mechanism to track locations while establishing safe zones and analyzing their movement patterns for future predictions.

A high-level architecture diagram of the entire proposed system is shown in figure 3.1.1.

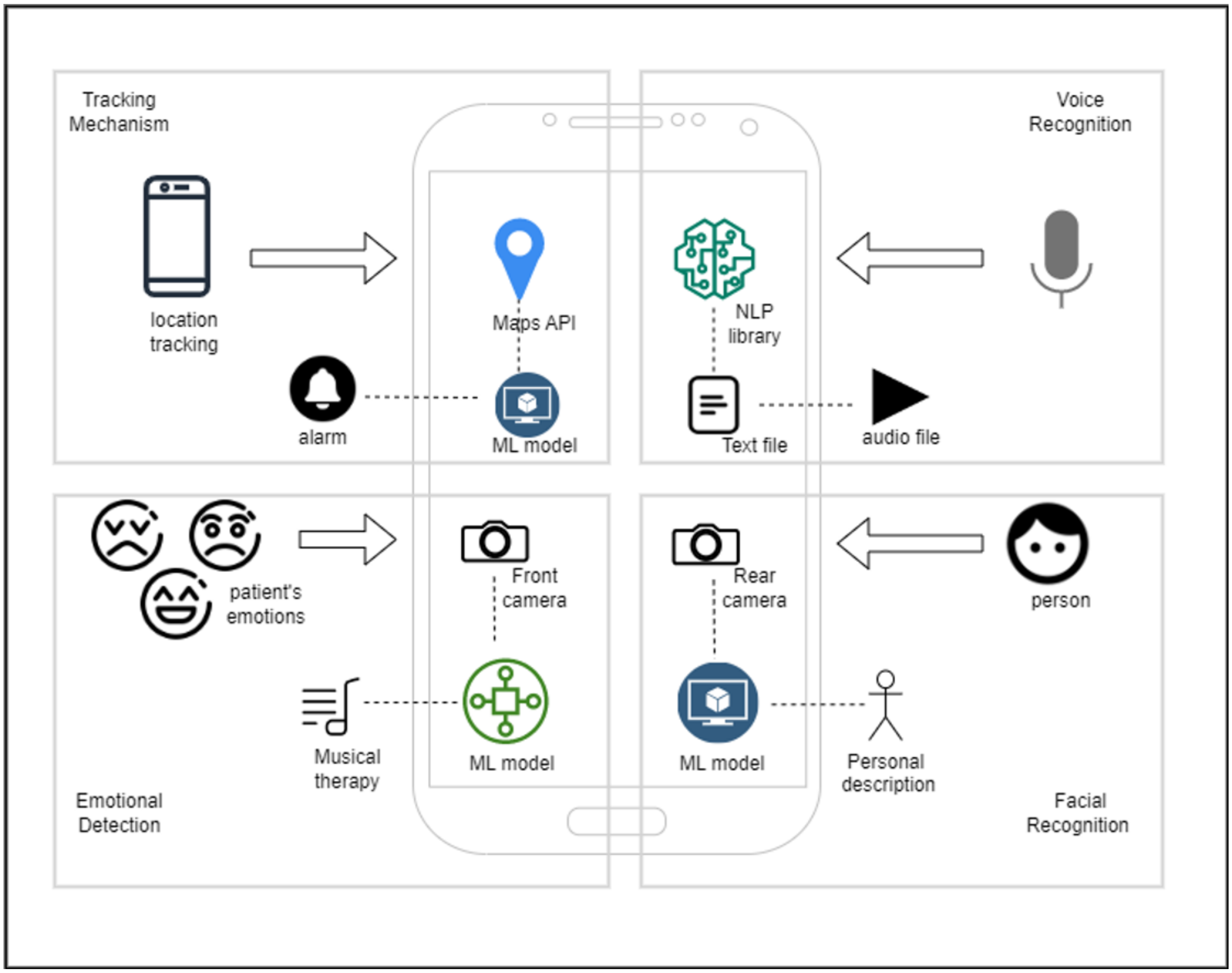

Figure 3.1. 1 : High-level system Diagram of entire Proposed System

Software Diagram of Analyze Wandering and Predict Future Movement Component

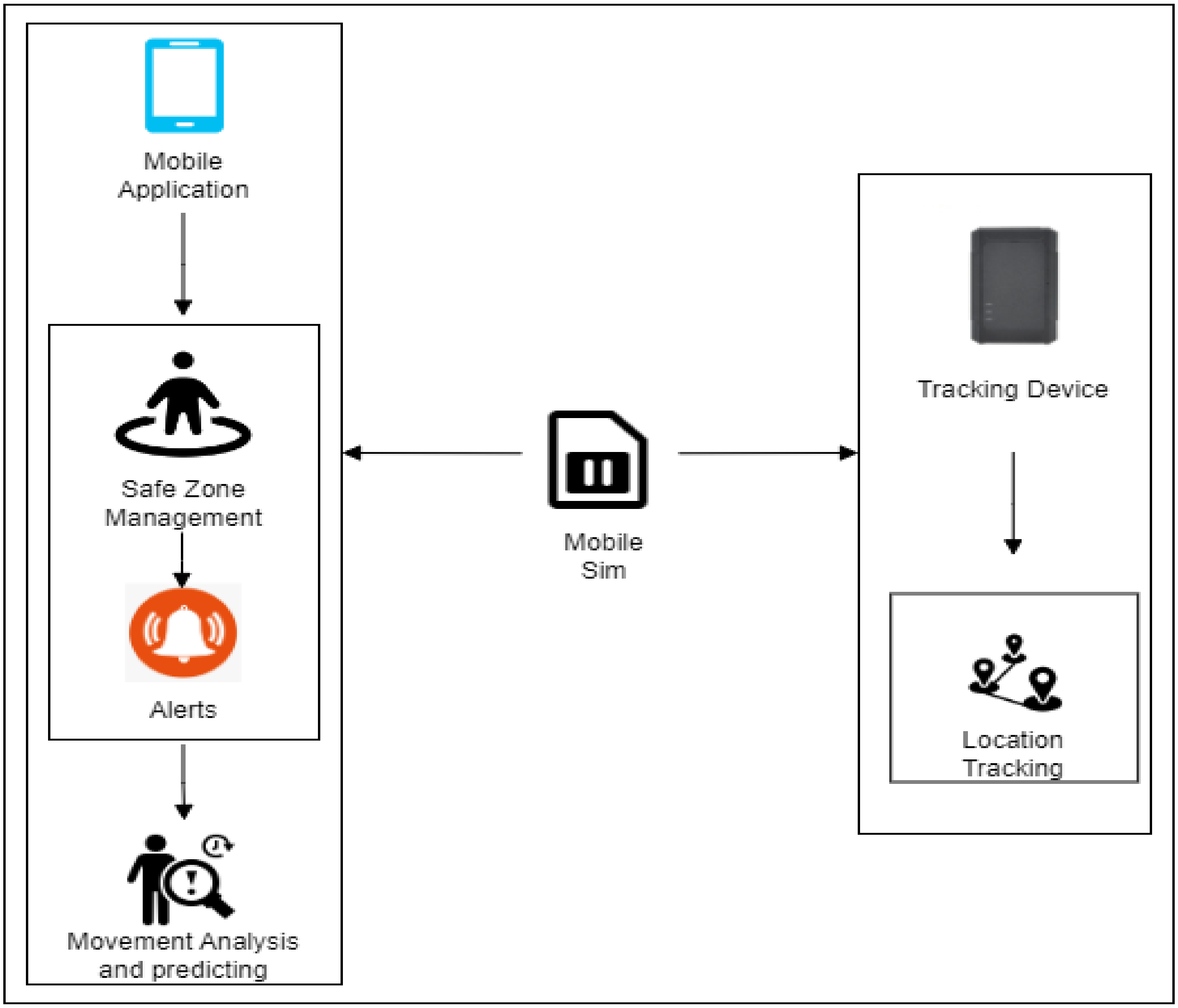

Figure 3.1. 2 : Software Diagram of Analyze Wandering and Predict Future Movement Component

This "Analyze wandering and predict future movement" function is part of the system designed to keep dementia sufferers safe from injury and danger. This suggested capability allows carers to keep their attention on the patients, analyze their previous moves, and create safe zones without physically being with them or having a significant impact on their everyday lives.

Figure 3.1.2 shows the adoption of a cutting-edge tracking device designed to assure continuous monitoring and patient safety. This device is a vital companion for the sufferer, and it is always with them. Its connectivity is created by using the device's unique IMEI number, which smoothly connects it to the caregiver's mobile phone. This link is made feasible by activating the device with a mobile SIM card, making it an important component of the patient's safety and well-being.

The tracking device harnesses the extensive reach of cellular networks, tapping into established cellular bands that blanket virtually every corner of the map. These bands facilitate the transmission of signals crucial for keeping tabs on the patient's location and well-being. What sets this system apart is its impressive real-time tracking capability, with the live location of the patient being updated at a remarkable frequency of every 10 seconds. This relentless vigilance ensures that caregivers have up-to-the-minute information at their fingertips, enhancing their ability to respond promptly to any changes or emergencies.

In addition to continuous location tracking, carers have the ability to set safe zones or safety parameters based on the patient's present position. These programmable safety zones operate as virtual limits, adding an extra layer of security. When the patient enters one of these predetermined zones, the system immediately sends notifications to the carers. This dynamic alert system guarantees that caregivers are promptly aware of any deviations from the specified safety parameters, allowing them to take prompt and appropriate action while constantly monitoring the patient.

Furthermore, the system boasts a robust data management component, with every location-related record meticulously stored in the backend of the application. These records serve as a valuable dataset, laying the foundation for the future location prediction functionality of the system depicted in Figure 3.1.2. By harnessing the historical location data, the system can employ advanced algorithms to forecast the patient's future movements and locations, providing caregivers with even greater insights and foresight into their patient's well-being.

3.1.2. Data Collection Methods

The initial part of this research project prioritizes information gathering and detailed analysis. This critical stage serves as the foundation for the entire project. We can discover, compile, and organize all of the important criteria for the effective development of the proposed device and system through this rigorous approach.

Initiating this step is imperative and must precede the actual implementation phase. It is during this preparatory period that we laid the groundwork for building a perfect, holistic solution that effectively addresses the challenges associated with dementia care. The requirements gathered during this phase serve as the blueprint for the subsequent stages of the project, guiding its development in a focused and informed manner.

Various methodologies and approaches have been employed to facilitate the requirement gathering process. These methods are designed to ensure that no essential detail or aspect is overlooked. Through comprehensive requirement gathering, we aim to create a solution that not only meets but exceeds the needs and expectations of caregivers and dementia patients alike.

- Read research papers, articles, and journals about wandering.
- Identifying existing tools and devices.
- Conducting a survey to gather information.
- Have physical interviews with caregivers of some patients.

Through a rigorous examination of research papers and scholarly articles, we have meticulously identified and garnered precise insights into the requirements essential for our project. This extensive review of existing literature not only furnished us with a comprehensive understanding of the field but also shed light on the capabilities of current tools and devices. This knowledge proved invaluable in pinpointing the precise research gap that our project seeks to address.

To further enrich our requirement gathering process, we employed a dual approach that included surveys and interviews. These methods were chosen strategically to capture a diverse range of perspectives and ideas. Given the constraints of time, surveys offered an efficient means to collect data and insights from a broader audience. Meanwhile, physical interviews proved indispensable in grounding our research by uncovering requirements at the grassroots level.

We recognized the critical necessity of a vast and diverse dataset in our pursuit of building a strong and highly accurate machine learning model. To accomplish this goal, I formed a tight cooperation with a family and developed a deep connection with them, all with the overall purpose of collecting thorough data on the daily lives and movements of a 62-year-old male dementia patient. This endeavor aimed to generate a large and significant dataset that would serve as the foundation for the accuracy and reliability of our machine learning model.

Over the course of several months, spanning from the 1st of March 2023 to the 30th of June 2023, meticulous efforts were made to meticulously document the patient's travels and locations. This period of data collection was chosen for its substantial timeframe, ensuring that we capture a wide array of experiences and scenarios that the patient encountered. Every place that the patient visited during this timeframe became a data point in our dataset, contributing to the holistic understanding of their movements and routines.

The patient's journey was chronicled with great care and precision. This included details about the places visited, the duration of their stay at each location, and any relevant contextual information. Such comprehensive data was vital not only for the immediate application of the tracking device but also for laying the foundation for a machine learning model that could reliably predict future movements and behaviors.

In essence, the commitment to gathering data for this senior dementia sufferer was both scientific and extremely humanistic. It was motivated by a genuine desire to improve the quality of life for people with cognitive problems and to provide effective tools to carers to ensure their safety and well-being. This dataset, created out of compassion and determination, exemplifies the power of technology to improve the lives of those in need. It is a key resource that will serve as the foundation for the construction of a machine learning model that can truly make a difference in dementia treatment.

The combination of these approaches resulted in a well-rounded and holistic understanding of the needs required for the success of our project. We have laid a solid foundation for our solution by drawing on the viewpoints and experiences of both specialists in the industry and members of the general public. This extensive requirement gathering method has positioned our project to satisfy the needs and ambitions of carers and dementia patients successfully and empathetically.

3.1.3. Tools and Technologies

Tools:

- Google Colab – Used to train and run machine learning models using cloud resources.
- Jupyter Notebook – Used to train and run the machine learning models locally.
- Visual Studio Code – IDE used as the development environment.
- VT03D Portable Tracking Device – To track patients' locations and map related features.
- GitLab – Used for version controlling.
- Expo-CLI – Used to install expo libraries to react-native applications.
- Postman – Used to test backend APIs.
- Microsoft Teams/WhatsApp/Zoom – Team meetings and connectivity

Technologies:

- React-Native – Used to build the front end of the system (cross-platform mobile application)
- Expo – A set of tools and services that makes the app development and build process much easier.
- Python – The language used to implement the backend including the ML models.
- FastAPI – A high-performing web framework for building APIs using Python.
- Firebase – Cloud-hosted NoSQL document database to store data
- Google Map API – For map implementations and configurations.

3.2 Commercialization aspect of the project

In our pursuit of commercializing our mobile application, which holds immense potential to benefit individuals worldwide, we recognize the need for a multifaceted approach that aligns with current global trends and user behaviors. Given that our application operates in the international language of English, its reach extends far beyond the borders of Sri Lanka, making it accessible and relevant to a global audience. To ensure swift and widespread adoption, we have strategically identified several key avenues for commercialization, with a primary focus on harnessing the immense power of social media platforms.

In today's digital landscape, social media stands out as a dynamic and influential force. With millions of users spending a substantial portion of their daily lives on platforms such as Facebook, WhatsApp, Instagram, and YouTube, leveraging these channels for advertising and promotion is not only prudent but essential. Through targeted and engaging adverts on these platforms, we can effectively introduce our application to a vast and diverse consumer base, transcending geographical boundaries.

Furthermore, we have recognized the importance of content providers in shaping trends and boosting user engagement. Platforms like YouTube, Twitch, and Trovo are home to a growing community of content creators with large followings. By selectively sponsoring and supporting these influencers, we can use their reach and influence to raise awareness about our system within their respective communities. This spontaneous recommendation can help us create confidence and credibility for our application.

To broaden our reach, we intend to work closely with healthcare organizations such as hospitals and clinics. Within their particular communities, these institutions provide reliable sources of knowledge and care. We can design targeted awareness programs that appeal to both healthcare professionals and patients by collaborating with them. This strategy ensures that our application reaches people from all walks of life, regardless of financial status.

We recognize the lasting power of conventional media in addition to digital platforms. For example, leaflets can be a useful instrument for increasing public awareness of our product, particularly within rural communities. We also recognize the importance of radio and podcasts, which continue to have a loyal following. Sponsoring radio shows and podcasts that cater to our target audience can be a beneficial outlet for advertising our product and its benefits.

Table 3.2. 1: Budget of the proposed system

Item	Estimated Cost (LKR)
Tracking Device	16,000
Hosting	10,000
App publishing cost on the Google Play store	5,000
Internet & Utility Costs	10,000
Total estimated cost	41,000

3.3 Testing and Implementation

3.3.1. Implementation

Our system's implementation is a methodically planned endeavor that leans heavily on the abundance of knowledge we have already accumulated. Our strategy revolves around the incorporation of current products and technology that contribute directly or indirectly to the realization of the proposed system. We intend to make the required connections with various devices, tools, and systems to produce a smooth and comprehensive solution by expanding on this base and systematically improving functions.

The use of pre-existing devices and technology is one of the primary guiding principles of our execution strategy. This method not only speeds up the development process, but it also ensures that we capitalize on established standards and best practices. By doing so, we hope to solve some of the most common complaints stated by users of existing devices on the market, such as difficulties with accuracy, cost, and complexity.

In response to these common customer issues, we put a major emphasis on enhancing accuracy, cost-effectiveness, and user-friendliness during the deployment process. We are devoted to improving and refining our system's tracking capabilities in order to present users with the most accurate and reliable information available. At the same time, we are conscious of cost considerations and seek to provide a solution that is not only accessible but also cost-effective.

To start this implementation journey, we initiated a comprehensive requirement analysis. This crucial step allowed us to gather and document all the essential requirements that will guide the development process. These requirements serve as our blueprint, outlining the features, functionalities, and performance expectations of the system. They represent the foundation upon which we build a solution that not only meets but exceeds the needs and expectations of our users. Those requirements are listed below.

Functional requirements

- Identify and monitor the patient's location.
- Identify and establish correct safe zones upon the caregiver's input.
- Maintain historical records separately.
- Predict the patient's future movements.
- Constantly monitor the patient's location.

Non-functional requirements

- Accuracy – This is a key feature since one of the complaints from users is most of the
existing applications are not accurate. It is important to show real-time data.
- Usability – System and operations need to be easily understandable by providing necessary instructions.
- Accessibility – Device and necessary instructions will be provided. The user only needs to have a smartphone.
- Reliability – Need to be reliable when displaying details such as date, time and weather.
- Well optimized – The device needs to be optimized well with the proposed system for the user to have a pleasant experience while using the mobile application.

User requirements

- Users should have a smartphone to use the mobile application.
- Users should have English knowledge to understand the instructions and given guidelines.
- Users must have some knowledge regarding mobile applications.

For the implementations of the map interfaces, it consists of both server side and client-side implementations, client-side implementations mean the mobile application and the server-side implementation means the allowing users to user map related functionalities such as geofencing and routing. React Native has been used to develop mobile applications while map services are called using Google map API. It has been developed to show the live locations and live movements of the person with the tracking device.

```javascript
const END_POINT =
  "https://6bc9-2402-d000-8130-51be-f9df-fe08-d08b-5577.ngrok-free.app"; // Replace with your server's URL
import axios from "axios";

export const API_KEY = "AIzaSyByO8RKhNqjGYw4LnknmMqwxyyyOqKQ9G8";

const api = axios.create({
  baseURL: END_POINT, // Replace with your server's URL
  timeout: 10000, // Adjust the timeout as needed
});

export default api;
```

Figure 3.3. 1: Usage of Google Map API to implement functions.

```javascript
const geocode = async () => {
  const geocodeLocation = await Location.geocodeAsync(address);
  console.log("geolocation:", geocodeLocation);
};

const reverseGeocodeAsync = async () => {…
};

const requestLocationPermission = async () => {…
};

const getCurrentPosition = async () => {
  const { status } = await Location.requestForegroundPermissionsAsync();
  if (status !== "granted") {
    console.log("Location permission denied!");
    return;
  }

  try {
    const location = await Location.getCurrentPositionAsync({});
    const { latitude, longitude } = location.coords;
    setLatu(parseFloat(latitude));
    setLong(parseFloat(longitude));
    console.log("Current position:", latitude, longitude);
    console.log("Location:", location);
  } catch (error) {
    console.log("Error getting location:", error);
  }
};

const onRegionChange = (region) => {
  console.log("region :", region);
};

useEffect(() => {
  getCurrentPosition();
}, []);
```

Figure 3.3. 2: Display current location.

I have used the sophisticated geofencing and geocoding facilities generously supplied by the Google Maps API to create safe zones and dynamically alter them based on the user's current location. This feature allows users to define safe zones by entering particular geographical coordinates (latitude and longitude) for each chosen location. These coordinates are carefully recorded, resulting in a map-based digital representation of each established safe zone.

Users are reminded to define a minimum of three and a maximum of four sites to ensure the usefulness of this safety feature. This thoughtful limitation not only improves the tool's utility but also aligns with practical reasons for ensuring a high level of security and accuracy. Once these safe zones are recognized and recorded by their coordinates, they are integrated into the larger geographical environment, thus creating digital borders within the physical world.

```
const showLocationInterest = () => {
  return locationInterest.map((item, index) => {
    return (
      <Marker
        key={index}
        coordinate={item.location}
        title={item.title}
        description={item.description}
      />
    );
  });
};

const geocode = async () => {
  const geocodeLocation = await Location.geocodeAsync(address);
  console.log("geolocation:", geocodeLocation);
};

const reverseGeocodeAsync = async () => {
  try {
    const latitude = parseFloat(latu);
    const longitude = parseFloat(long);
    console.log("latitude:", latitude);
    console.log("longitude:", longitude);
    const location = await Location.reverseGeocodeAsync({
      latitude,
      longitude,
    });
    console.log("Reverse geocoded location:", location);
  } catch (error) {
    console.log("Error during reverse geocoding:", error);
  }
};
```

Figure 3.3. 3: Geofencing/Geocoding services

Predefined safe zones serve as virtual safeguards, allowing the system to continuously monitor the user's location and trigger alerts or actions when they enter or exit these predefined safe zones. Text messages are sent to the caregivers registered mobile phone constantly while tracking the live location of the patient despite the emergency.

```
import Twilio from 'react-native-twilio';

const sendSMS = (message) => {
  Twilio.initWithToken('YOUR_TWILIO_ACCOUNT_SID', 'YOUR_TWILIO_AUTH_TOKEN');

  Twilio.sendMessage({
    body: message,
    to: 'RECIPIENT_PHONE_NUMBER',
    from: 'TWILIO_PHONE_NUMBER',
  }).then((result) => {
    // Handle the SMS sending result
  });
};
```

Figure 3.3. 4: Triggering alerts as messages and sending to the caregivers.

Machine Learning Models

- **Decision Tree Algorithm**

At first, while doing tracking device related tasks, I closely associated with a family and gathered data for 4 months and built a data. The Decision Tree algorithm was implemented first in order to predict locations. The following steps are implemented in order to build a successful model.

- **Importing libraries and loading dataset**

```python
# Import necessary libraries
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

from sklearn.linear_model import LogisticRegression
from sklearn.neighbors import KNeighborsClassifier
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score, confusion_matrix, ConfusionMatrixDisplay

data = pd.read_csv("Datasets/Dataset_Locations.csv")
data.head(5)
```

	Date	Day of the Week	Time of the Day	Reason	Location
0	3/1/2023	Wednesday	Morning	Normal routine	Home
1	3/1/2023	Wednesday	Morning	Daily Chores	Home
2	3/1/2023	Wednesday	Morning	Personal Habit	Backyard
3	3/1/2023	Wednesday	Morning	Daily Morning Visit	Garden
4	3/1/2023	Wednesday	Morning	Breakfast	Home

Figure 3.3. 5: Imported libraries for Decision Tree Algorithm

This section imports necessary libraries for data manipulation, visualization, and machine learning. It also loads a dataset named "Dataset_Locations.csv" using Pandas and displays the first 5 rows of the dataset.

- **Data preprocessing**

```
[ ]  data = data[~(data['Date'] == 0)]
     data = data[~(data['Day of the Week'] == 0)]
     data = data[~(data['Time of the Day'] == 0)]
     data = data[~(data['Location'] == 0)]
     data = data[~(data['Reason'] == 0)]

[ ]  data.shape

     (4395, 5)

[ ]  # remove null values
     null_rows = data.isnull().any(axis=1)  # Check if any value in each row is null
     data = data[~(null_rows)]
     data.shape

     (4100, 5)

[ ]  # remove dupicates rows

     # Remove duplicate rows
     data = data.drop_duplicates(subset=['Date', 'Day of the Week', 'Time of the Day', 'Location', 'Reason'])

     # Print the DataFrame without duplicates
     print(data)
     data.shape

                Date Day of the Week Time of the Day               Reason  \
     0      3/1/2023       Wednesday         Morning       Normal routine
     1      3/1/2023       Wednesday         Morning         Daily Chores
     2      3/1/2023       Wednesday         Morning       Personal Habit
     3      3/1/2023       Wednesday         Morning  Daily Morning Visit
     4      3/1/2023       Wednesday         Morning            Breakfast
     ...         ...             ...             ...                  ...
```

Figure 3.3. 6: Data preprocessing of Decision Tree Algorithm

In this section, various data preprocessing steps are performed. Rows with specific conditions (e.g., Date, Day of the Week, Time of the Day, Location, and Reason equal to 0) are removed. Rows with any null values are removed. Duplicate rows based on specific columns are dropped.

- **Data visualization**

```
[ ] locations = data['Location'].value_counts()
    print((locations))

    Home                           1808
    Garden                          543
    Backyard                        241
    Paddy Fields                    186
    Home                            119
                                   ...
    Matara Town                       1
    Relatives House - Garden          1
    Hiriketiya Junction               1
    Nupe Junction                     1
    pubb                              1
    Name: Location, Length: 79, dtype: int64

[ ] # Increase the width of the graph
    plt.figure(figsize=(20, 8))

    data['Location'].value_counts().plot()
    plt.show()
```

Figure 3.3. 7: Visualizing the data for Decision Tree Algorithm

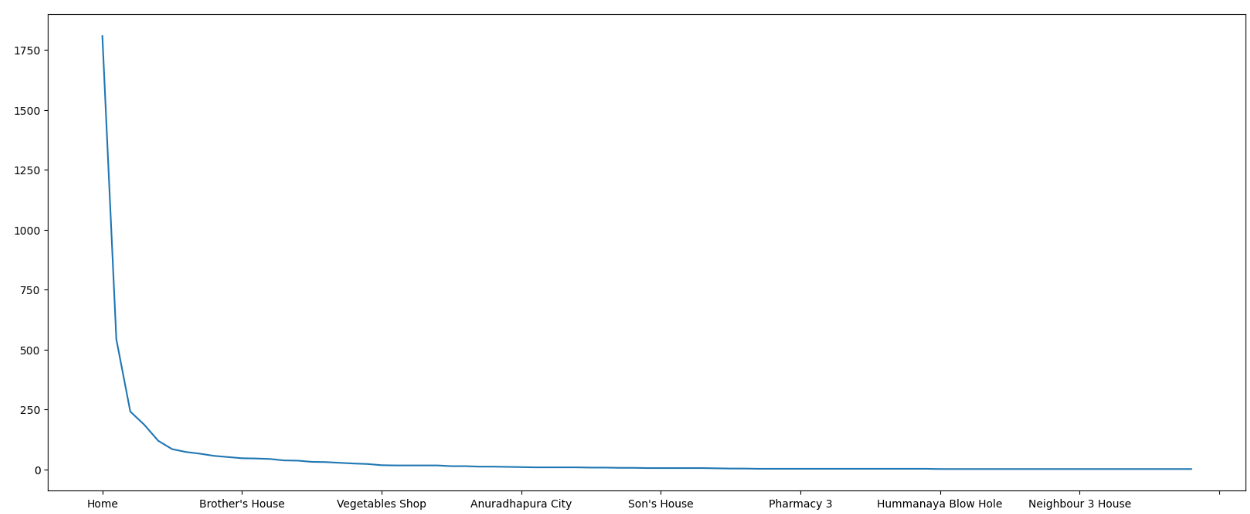

Figure 3.3. 8: Plotting the data of Decision Tree Algorithm

This section explores and visualizes the distribution of Location values in the dataset. It calculates the count of each unique Location value and plots a bar chart to visualize the distribution.

- **Feature Engineering**

```
[ ] label_to_number = {}
    location_arr = []
    for index, label in enumerate(locations.index):
        label_to_number[label] = index
        location_arr.append(label)

    print(label_to_number)

    {'Home': 0, 'Garden': 1, 'Backyard': 2, 'Paddy Fields': 3, 'Home ': 4, 'Public Bus Stop': 5, 'Bakery': 6, 'Matara Public Bus Stand': 7, 'Temple': 8, 'Rahula College - Matara': 9, "Brother's House": 10, 'Nei

[ ] # Use the map() function to replace the values in the location column
    data["Location"] = data["Location"].map(label_to_number)

    data['Location'].value_counts()

    0     1808
    1      543
    2      241
    3      186
    4      119
          ...
    74       1
    75       1
    76       1
    77       1
    78       1
    Name: Location, Length: 79, dtype: int64
```

Figure 3.3. 9: Feature Engineering of Decision Tree Algorithm

In this section, feature engineering is performed on the dataset. Location, Reason, Time of the Day, and Day of the Week columns are mapped to numeric values.

- **Training and evaluating the model.**

```
# Split the dataset into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2)
```

```
def model_executor_and_acuracy(model):
    # Train the model on the training data
    model.fit(X_train, y_train)

    # Make predictions on the test data
    y_pred = model.predict(X_test)

    print(f"<<<<====== {model} ====>>>>")
    # Calculate the accuracy of the model
    accuracy = accuracy_score(y_test, y_pred)
    print("Accuracy:", accuracy)
```

```
# Create a logistic regression model
logreg = LogisticRegression()
# Create a KNeighborsClassifier model
knc = KNeighborsClassifier(n_neighbors=2)
# Create a DecisionTreeClassifier model
dtc = DecisionTreeClassifier()
models = [logreg, dtc, knc]
```

Figure 3.3. 10: Training and evaluating the various models.

In this section, the dataset is split into features (X) and the target variable (y). Three different machine learning models (Logistic Regression, Decision Tree, K-Nearest Neighbors) are created and evaluated for accuracy. According to this, I have got an accuracy y of 94.16 for the Decision Tree algorithm.

- **Making predictions**

```
[ ] from datetime import datetime

    date = "3/5/2023"
    day_of_week = "Sunday"
    time_of_day = "Morning"
    s_reason = "Medicine"

    numeric_date = pd.to_datetime(date, format='%m/%d/%Y')
    numeric_date = (numeric_date - pd.Timestamp('1970-01-01')).days

    day_of_week = week_day_mapping[day_of_week]
    time_of_day = day_mapping[time_of_day]

    if s_reason in reason_to_number:
        s_reason = reason_to_number[s_reason]
    else:
        s_reason = len(reason_to_number)

    df = pd.DataFrame({'Date': [numeric_date], 'Day of the Week': [day_of_week], 'Time of the Day': [time_of_day], 'Reason': [s_reason]})

    sample = df.iloc[:,:].values

    predict_res = load_mode.predict(sample)
    print('predic', predict_res)
    print("Predict Location : ", location_arr[predict_res[0]])
```

Figure 3.3. 11: Making predictions using Decision Tree Algorithm

In this section, a sample input is created for prediction, where the user provides a date, day of the week, time of day, and reason. This input is then converted to a numeric format, and the loaded Decision Tree model is used to make a location prediction based on the input. The predicted location is displayed.

➢ Random Forest Algorithm

After finishing the configurations with the tracking device, it was suggested that with the data that are been saved from the device cannot be trained by a decision tree algorithm since it captures the latitude and longitude of the location. So after doing further analysis, it was evident that Random Forest Algorithm is recommended for those kind of scenarios. To build that ML model, the following steps have been implemented.

- **Importing libraries and loading dataset**

```
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.ensemble import RandomForestRegressor
from sklearn.metrics import mean_absolute_error, mean_squared_error

# Load the CSV file into a Pandas DataFrame
csv_file_path = 'gpsdata.csv'
df_csv = pd.read_csv(csv_file_path)
```

Figure 3.3. 12: Importing libraries to Random Forest Algorithm

In this section, necessary libraries are imported. Pandas is used for data manipulation, train_test_split for splitting data, RandomForestRegressor for building a random forest regression model, and mean_absolute_error and mean_squared_error for evaluating model performance. Then a CSV file named 'gpsdata.csv' has been loaded into a Pandas DataFrame.

- **Data cleaning**

```
# Skip irrelevant rows and keep only relevant columns
df_clean = df_csv.iloc[2:].reset_index(drop=True)
df_clean.columns = df_csv.iloc[1]
```

Figure 3.3. 13: Cleaning data from Random Forest Algorithm

This section skips the first two rows (which are irrelevant) and resets the index. The column names are set to the values from the third row, which presumably contain column headers.

- **Data preprocessing**

```
# Convert columns df_clean['GPS Time'] = pd.to_datetime(df_clean['GPS Time'])
df_clean['Latitude'] = pd.to_numeric(df_clean['Latitude'], errors='coerce')
df_clean['Longitude'] = pd.to_numeric(df_clean['Longitude'], errors='coerce')

# Identify the data type of 'GPS Time'
print(df_clean['GPS Time'].dtype)

object

# Convert object data type to date-time
df_clean['GPS Time'] = pd.to_datetime(df_clean['GPS Time'])
```

Figure 3.3. 14: Data preprocessing of Random Forest Algorithm

Here, data preprocessing is performed. The 'GPS Time' column is converted to datetime format. The 'Latitude' and 'Longitude' columns are converted to numeric format, and any parsing errors are set to NaN using the errors='coerce' argument.

- **Extracting date time components**

```
# Extract year, month, day, hour, minute, and second from the 'GPS Time' column
df_clean['year'] = df_clean['GPS Time'].dt.year
df_clean['month'] = df_clean['GPS Time'].dt.month
df_clean['day'] = df_clean['GPS Time'].dt.day
df_clean['hour'] = df_clean['GPS Time'].dt.hour
df_clean['minute'] = df_clean['GPS Time'].dt.minute
df_clean['second'] = df_clean['GPS Time'].dt.second
```

Figure 3.3. 15: Extracting components in Random Forest Algorithm

This part extracts year, month, day, hour, minute, and second components from the 'GPS Time' column and creates new columns for each component in the DataFrame.

- **Defining features and target variables**

```
# Features and target variables
features = ['year', 'month', 'day', 'hour', 'minute', 'second']
target_latitude = 'Latitude'
target_longitude = 'Longitude'
```

Figure 3.3. 16: Defining features and target variables in Random Forest Algorithm

Here, the features for the regression model are defined as the extracted date and time components. The target variables are set as 'Latitude' and 'Longitude' columns.

- **Splitting the data in to training and testing datasets**

```
# Split data into training and test sets
X = df_clean[features]
y_latitude = df_clean[target_latitude]
y_longitude = df_clean[target_longitude]

X_train_lat, X_test_lat, y_train_lat, y_test_lat = train_test_split(X, y_latitude, test_size=0.2, random_state=42)
X_train_long, X_test_long, y_train_long, y_test_long = train_test_split(X, y_longitude, test_size=0.2, random_state=42)
```

Figure 3.3. 17: Splitting data to training and testing in Random Forest Algorithm

This section splits the data into training and test sets separately for latitude and longitude predictions using the train_test_split function. A random seed is set to ensure reproducibility.

- **Initializing and training Random Forest model**

```
# Initialize and train the Random Forest models
rf_model_lat = RandomForestRegressor(random_state=42)
rf_model_long = RandomForestRegressor(random_state=42)

rf_model_lat.fit(X_train_lat, y_train_lat)
rf_model_long.fit(X_train_long, y_train_long)
```

Figure 3.3. 18: Initializing the Random Forest Algorithm

Two Random Forest Regressor models are initialized and trained separately for latitude and longitude using the training data

- **Making sample predictions**

```
# Make a sample prediction for a given datetime
sample_datetime = pd.DataFrame({
    'year': [2023],
    'month': [9],
    'day': [1],
    'hour': [10],
    'minute': [0],
    'second': [0]
})
```

```
predicted_latitude = rf_model_lat.predict(sample_datetime)
predicted_longitude = rf_model_long.predict(sample_datetime)
```

```
print(f"Predicted Latitude: {predicted_latitude[0]}")
print(f"Predicted Longitude: {predicted_longitude[0]}")
```

```
Predicted Latitude: 8.006238390000004
Predicted Longitude: 80.91337976999996
```

Figure 3.3. 19: Making Sample predictions in Random Forest Algorithm

This code essentially demonstrates how to load and preprocess GPS data, train random forest regression models for latitude and longitude prediction and make a sample prediction using these models.

Feasibility Study

The feasibility studies listed below are performed during the development process to evaluate the feasibility of implementation. The following description describes the features of scheduled feasibility, technical feasibility, and economic feasibility.

Schedule feasibility:

The proposed system with the device should be completed within the specified time. The Gantt chart shows the allocated time periods for each phase.

Technical feasibility:

team members need to understand the hardware and other physical components that have been used in the tracking device. Then to build the mobile application, the team members of the research study should have knowledge of computer programming languages. New technologies and components need to be studied in order.to build a perfect product.

Economic feasibility:

Since this research component included an IoT device, there are hardware and other physical components to be used. Under some cost constraints, all the members should use their respective resources within the price range. A less expensive but more productive approach should be followed.

3.3.2. Testing

The whole system will be tested utilizing a variety of testing methodologies such as unit testing, integration testing and user testing in order to find flaws and issues in the early stage of the application’s lifecycle. It should be released after completing all the testing. If there are any problems within this phase, they should be addressed before the product’s release. After clearance of the user testing, this application will be released for dementia patients and their caregivers.

To conduct a thorough evaluation of the system's performance and functionalities, the team created test cases for identified test scenarios.

Table 3.3.2. 1: Test whether live location is correctly tracking and refreshing.

Test Case ID	01
Test Case	The live location of the patient should be displayed correctly and should be updated frequently.
Test Scenario	Verify that the live location tracking updates every 10 seconds as expected.
Pre-condition	- Mobile application is running. - Tracking device is active.
Input	Patient's mobile device is in motion.
Expected output	- The live location should be updated every 10 seconds. - Caregivers should see the updated location on the map.
Actual output	- The live location is updating every 10 seconds. - Caregivers can see the updated location on the map.
Test status	Passed

Table 3.3.2. 2: Whether geo-fencing can be applied correctly.

Test Case ID	02
Test Case	The Geo-fencing feature should work correctly and must create safe zones/boundaries.
Test Scenario	Verify that caregivers can define safe zones within the map using geo-fencing.
Pre-condition	- Mobile application is running. - Caregiver is logged in.
Input	The caregiver selects an area of the map to set as the safe zone.
Expected output	- The safe zone should be successfully defined. - It should appear on the map. - No alerts should be triggered at this point.
Actual output	- The safe zone is successfully defined. - It appears on the map. - Alerts are not triggered at this point.
Test status	Passed

Table 3.3.2. 3: Whether alerts are correctly triggered to the caregivers.

Test Case ID	03
Test Case	When a patient crosses the defined safe zones, alerts need to be triggered and sent to caregivers' mobile phone as text messages.
Test Scenario	Verify that alerts are triggered when the patient crosses a defined safe zone.
Pre-condition	- Mobile application is running. - Geo-fencing is set up with at least one safe zone. - The patient's location is within a safe zone.
Input	Patient crosses the boundary of a defined safe zone.
Expected output	- Alerts should be triggered. - The system should send messages to the caregiver's mobile phone.
Actual output	- Alerts are triggering. - The system sends messages to the caregiver's mobile phone.
Test status	Passed

Table 3.3.2. 4: Whether location predictor works fine in emergency situations.

Test Case ID	04
Test Case	In emergency situations such as device malfunctions, location predictor must show the correct location.
Test Scenario	Verify that the machine learning model predicts the patient's location in case of an emergency.
Pre-condition	- Mobile application is running. - The machine learning model is integrated and active in the application.
Input	Patient's behavior or location indicates an emergency (e.g.- Device malfunction)
Expected output	The machine learning model should predict the patient's likely location, and this prediction should be shared with the caregiver along with an alert.
Actual output	Correct location has been predicted 96% of the occasions.
Test status	Passed

Table 3.3.2. 5: Whether application is working under heavy network traffic.

Test Case ID	05
Test Case	When application is used by many users at the same time, it should work without any obstacles or delays.
Test Scenario	Verify that the application performs well under heavy load when multiple caregivers tracking multiple patients simultaneously.
Pre-condition	Multiple caregivers are using the application simultaneously, tracking multiple patients.
Input	Continuous location updates and geo-fencing activities for multiple patients and caregivers.
Expected output	- The application should remain responsive. - Location updates should not significantly slow down or lag.
Actual output	- The application remains responsive. - Location updates are not slow down or lag on 95% of the occasions.
Test status	Passed

Table 3.3.2. 6: Whether patient's historical records can be retrieved.

Test Case ID	06
Test Case	Patient's historical data can be retrieved without any problems.
Test Scenario	Verify that caregivers can access and view historical location records of the patient.
Pre-condition	- Mobile application is running. - The patient's historical location data is available.
Input	Caregiver selects a date and time range to retrieve historical location data.
Expected output	The application should display a history of the patient's movements, including where and when they traveled during the specified time range.
Actual output	The application displays the history of the patient's movement and all the relevant details successfully.
Test status	Passed

Table 3.3.2. 7: Whether patient's historical data is exported.

Test Case ID	07
Test Case	All the data should be stored and exported in the patient’s history as documentation.
Test Scenario	Verify that caregivers can export historical location records for documentation or analysis.
Pre-condition	- Mobile application is running. - Historical location data is available.
Input	Caregiver selects a date and time range to export historical location data.
Expected output	All the records should be exported successfully.
Actual output	All the records export successfully.
Test status	Passed

Table 3.3.2. 8: Whether data privacy and security can be proven.

Test Case ID	08
Test Case	All the data should be protected with privacy and security terms.
Test Scenario	Verify that patient location data is securely stored and accessed only by authorized caregivers.
Pre-condition	- Mobile application is running. - Patient data is stored securely.
Input	Attempted unauthorized access to patient location records.
Expected output	- Unauthorized access should be denied. - Caregivers should only be able to access patient location data after proper authentication and authorization.
Actual output	- Unauthorized access is denied. - Caregivers can only be able to access patient location data after proper authentication and authorization.
Test status	Passed

The team was able to properly examine the system's performance and detect any potential flaws before deployment by following this detailed testing approach and building precise test cases.

4. RESULTS AND DISCUSSION

4.1 Results

For location prediction functionality, various algorithms have been used. In the early stages of the implementation, location name-based predictions have happened and for that algorithms such as Logistic Regression, K-Nearest Neighbor and Decision Tree have been considered and tested. In the below figure 4.1.1 it shows the used algorithms and the accuracies that have been gained for each ML model.

```
# calling method - model_executor_and_acuracy
for model in models:
    model_executor_and_acuracy(model)
```

```
<<<<====== LogisticRegression() ====>>>>
Accuracy: 0.48119325551232167
<<<<====== DecisionTreeClassifier() ====>>>>
Accuracy: 0.9416342412451362
<<<<====== KNeighborsClassifier(n_neighbors=2) ====>>>>
Accuracy: 0.7198443579766537
```

Figure 4.1. 1: Various Algorithms that have been used and accuracies of them.

As demonstrated above, accuracies for Logistic Regression, Decision Tree and K-Nearest Neighbor algorithms are 48.12%, 94.16% and 71.98% respectively.

Then after acquiring the location tracking device it was evident that Decision tree algorithm is not the most suitable when it comes to location predictions using latitude and longitude. So, in order to fulfil that, LSTM and Random Forest Regressor algorithms have been used. Although both are equal considering the accuracies, the result generating time and with LSTM being a RNN, it takes a lot of computational power, it was proven that Random Forest algorithm is the most suitable option. To determine the accuracy, MAE and MSE have been considered. The results are shown in figure 4.1.2 below.

```
# Predictions on the test set
y_pred_lat = rf_model_lat.predict(X_test_lat)
y_pred_long = rf_model_long.predict(X_test_long)

# Calculate Mean Absolute Error (MAE)
mae_lat = mean_absolute_error(y_test_lat, y_pred_lat)
mae_long = mean_absolute_error(y_test_long, y_pred_long)

# Calculate Mean Squared Error (MSE)
mse_lat = mean_squared_error(y_test_lat, y_pred_lat)
mse_long = mean_squared_error(y_test_long, y_pred_long)

# Print Mean Abssolute Errorrs and Mean Squared Errors for latitude and longitude
print("Mean Absolute Error for Latitude:", mae_lat)
print("Mean Absolute Error for Longitude:", mae_long)
print("\nMean Squared Error for Latitude:", mse_lat)
print("Mean Squared Error for Longitude:", mse_long)
```

```
Mean Absolute Error for Latitude: 0.0027349905006102955
Mean Absolute Error for Longitude: 0.0022434401084643635

Mean Squared Error for Latitude: 0.00018916616362823 64
Mean Squared Error for Longitude: 0.0002546713325623277
```

Figure 4.1. 2: MAE and MSE values for Random Forest Algorithm

As demonstrated above, MAE and MSE have been calculated separately for latitude and longitude. MAEs for latitude and longitude are 0.27% and 0.22% respectively. Then MSEs for latitude and longitude are 0.019% and 0.025%. Since the deviations are so small it is proven that accuracy of this model is high as well.

As demonstrated above, MAE and MSE have been calculated separately for latitude and longitude. MAEs for latitude and longitude are 0.27% and 0.22% respectively. Then MSEs for latitude and longitude are 0.019% and 0.025%. Since the deviations are so small it is proven that accuracy of this model is high as well.

When considering the map related functionalities, live location tracking mechanism is working correctly. Map indicator shows as a car logo since the tracker is a portable device which was made and meant to track vehicles. Also, there is a security restriction from the goggle regarding indicator changes, but we are trying to make it more user friendly and less confusing.

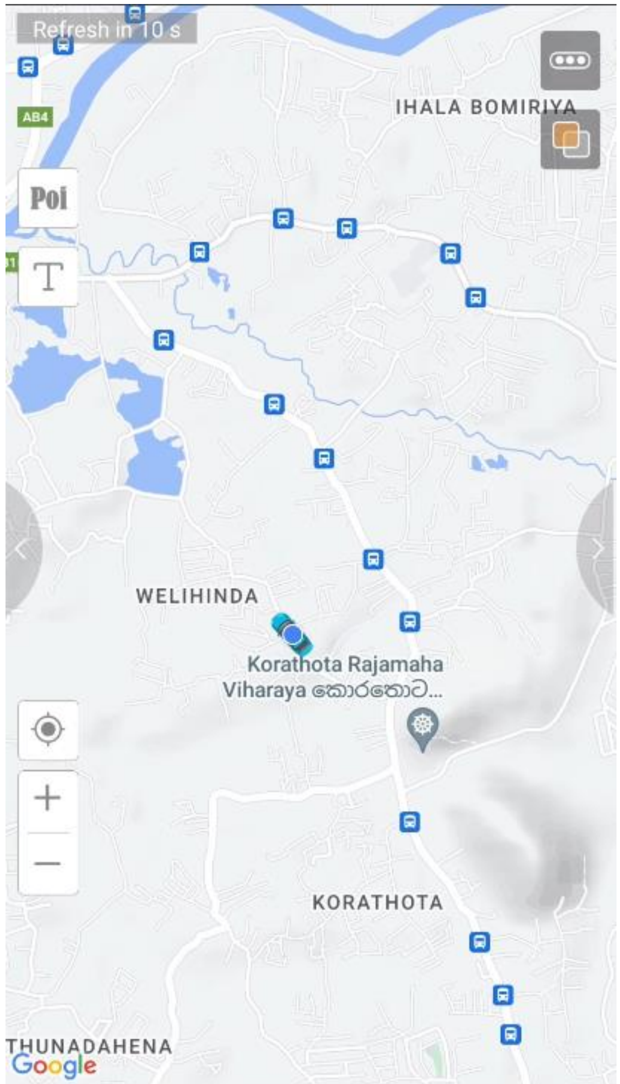

Figure 4.1. 3: When the patient is nor moving.

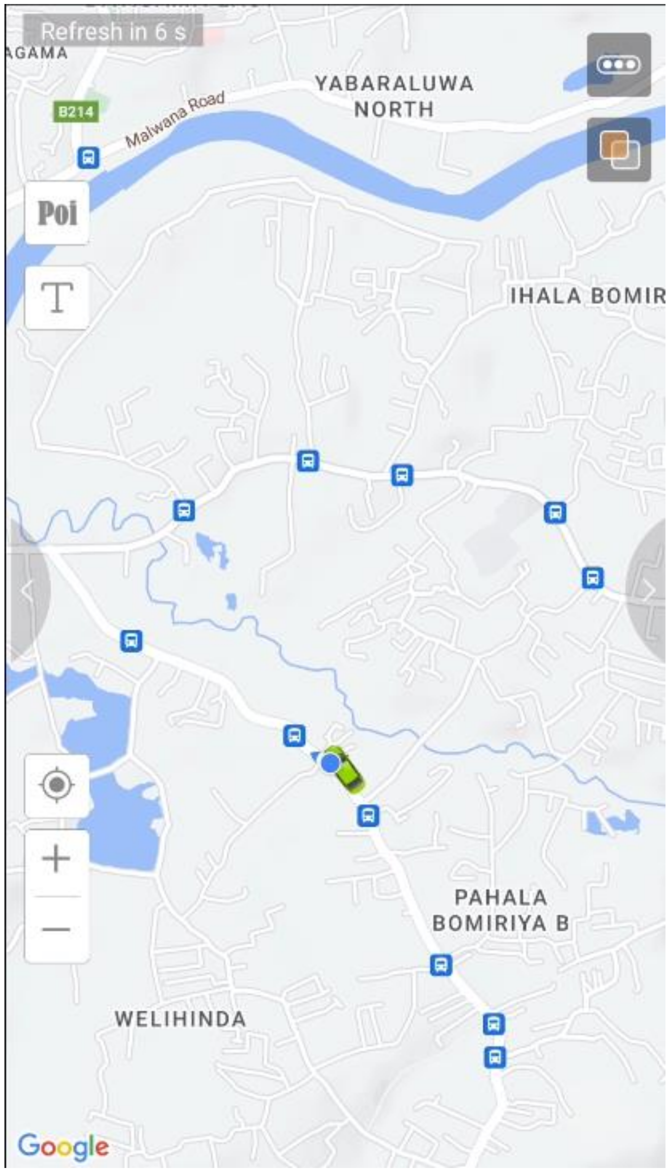

Figure 4.1. 4: When the patient is moving.

As shown in the above figures, the live location of the patient with the status as whether the person is moving or not. When moving, the indicator displays as light green. Then when the patient is not moving, the indicator displays in blue. This provides user friendly and easily recognizable details to the people who are watching.

Then to define safe zones/boundaries, geo fencing features have been used. The following figures emphasize that.

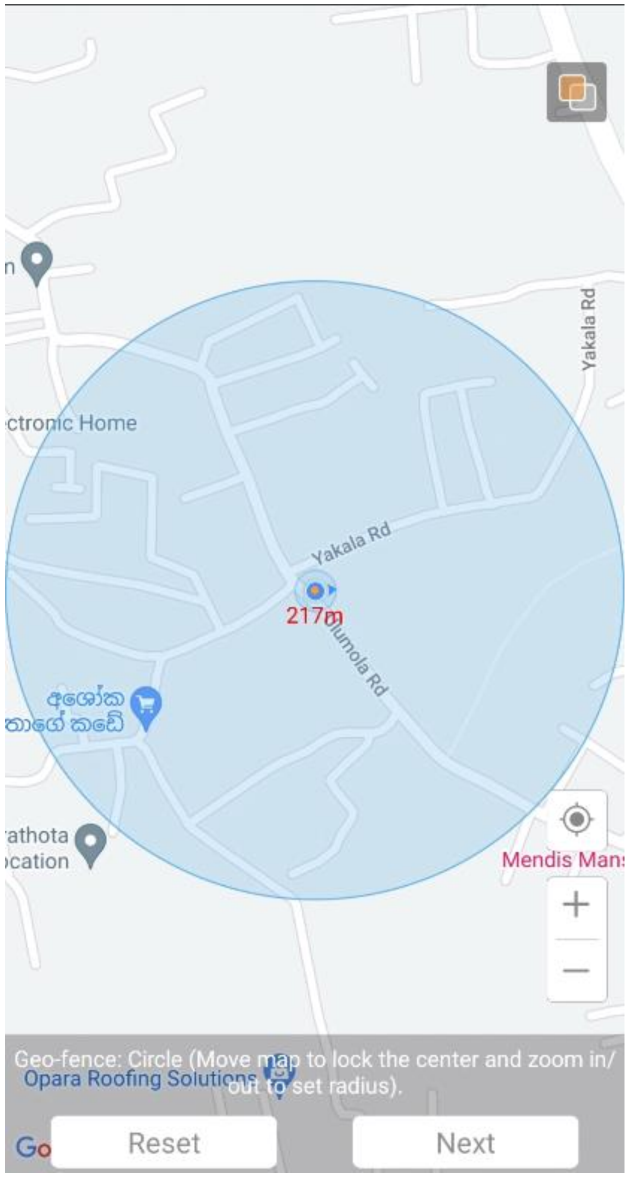

Figure 4.1. 5: Defining safe zones as a circle.

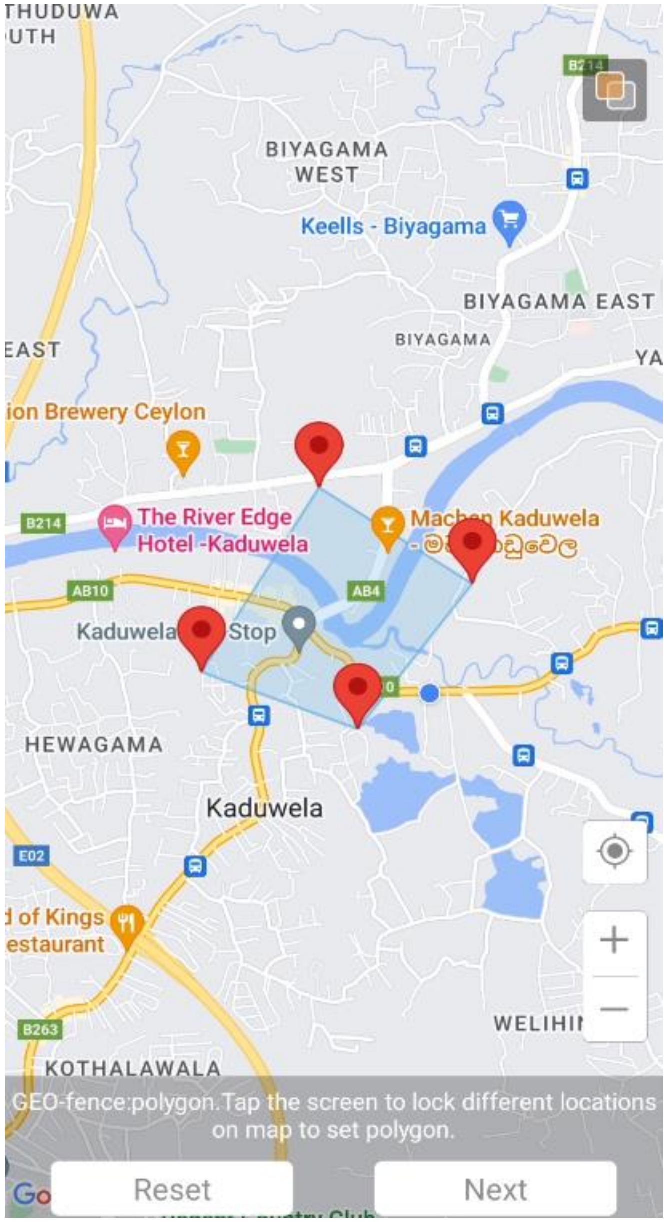

Figure 4.1. 6: Defining safe zones according to caregivers need.

Then Above figures showcases the two modes of defining safe zones. Figure 4.1.5 shows the default functionality where caregivers can define safe zones by centering on a particular location and with a equal radius around it. Figure 4.1.6 shows that caregivers can customize the safe zones according to their needs by marking minimum of 3 and maximum of 4 locations in the map.

The facility to view patients' historical records has been provided with this whole system and it can be demonstrated from the figures below.

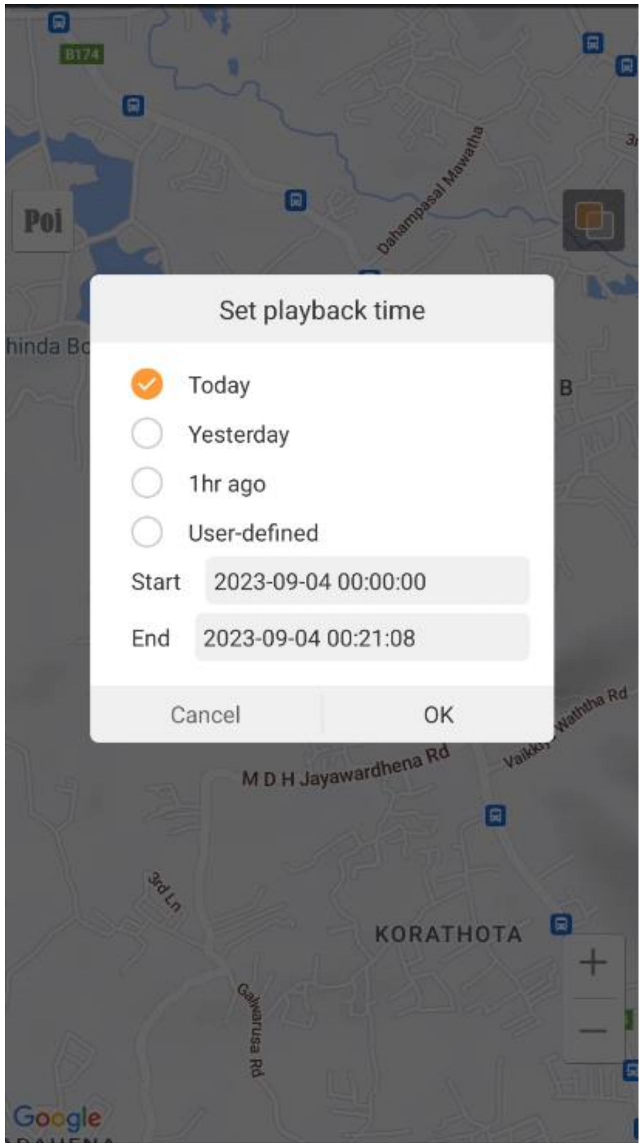

Figure 4.1. 7: Giving inputs to view patients past records.

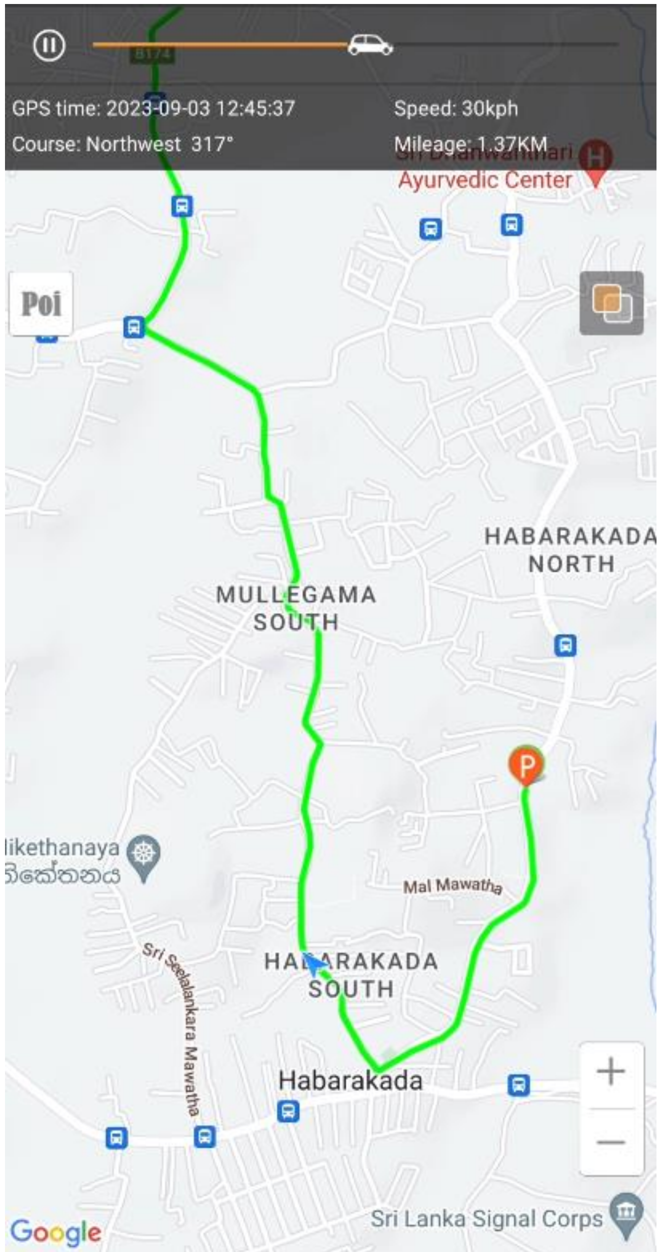

Figure 4.1. 8: Viewing playbacks of patient's movements.

Figure 4.1.7 shows how caregivers can provide inputs and search past records to their needs and figure 4.1.8 displays a playback of patient’s movements.

4.2 Research Findings

The study's goal was to address the difficulties caused by wandering behavior in dementia patients, as well as the strain placed on caregivers. The study's findings were based on a review of the literature, which comprised several research studies and journal articles. A Google Form was also used to collect data from caregivers in order to acquire a better understanding of their experiences and needs.

The designed mobile application, built using React-Native and using Firebase as the database, provides a multifaceted solution for improving dementia patient care. The application uses a location-tracking device, the VT03D portable device, to track dementia sufferers in real time. This device, which is enabled with a mobile SIM card and linked via its IMEI number, updates the patient's live location every 10 seconds, giving caregivers ongoing awareness of the patient's surroundings.

Caregivers have the authority to construct and change safe zones for patients. When a patient wearing the tracking device crosses established safe zones, the system sends fast alerts to caregivers' mobile phones via text message. This function improves patient safety and reduces the chance of wandering behavior. The application keeps complete historical records of patient mobility, including travel routes and timestamps. Caregivers have access to these records and can even relive previous events. This feature allows for a more in-depth analysis of patient behavior and habits.

For the location prediction mechanism, the study used Decision Tree and Random Forest algorithms to achieve a remarkable 94.16% accuracy in location prediction. The prediction mechanism aids carers in estimating the patient's future location, hence improving proactive care. In addition to Decision Tree algorithm, the study explored K-Nearest Neighbor and Logistic Regression algorithms for name-based location prediction. However, as compared to Decision Trees, these options produced lower accuracies. In emergency situations, such as device malfunctions or dead batteries, the location prediction system proves invaluable by providing insights into the projected patient position. This feature ensures that major incidents are handled in a timely manner.

4.3 Discussion

The achievements of this research study underscore the significance of the developed application in addressing the complex challenges faced by dementia patients and their caregivers. The discussion delves into the implications and limitations of these findings, emphasizing their contributions to improving the quality of life for dementia patients and reducing caregiver burden.

The application's real-time tracking and alerting system provides caregivers with essential tools to manage wandering behavior effectively. By enabling safe zones and sending alerts, caregivers can proactively ensure patient safety while alleviating the stress associated with constant monitoring.

Empowering dementia patients to move within predefined boundaries while maintaining their cognitive independence is a fundamental achievement of this study. This balance between autonomy and safety is crucial for improving the patient's overall well-being.

The high accuracy achieved by the location prediction mechanism, especially through Decision Trees and Random Forest algorithms, offers caregivers a reliable tool for planning and responding to potential situations. This adds an extra layer of security and confidence in patient care.

It is essential to acknowledge potential limitations, such as device dependency and patient cooperation. Future research could explore additional machine learning algorithms and enhance the application's user interface for better usability, aiming to further improve dementia care.

5. CONCLUSION

This research project addressed a critical issue in the treatment of dementia patients by developing an innovative application meant to improve patients' cognitive independence and minimize the loads carried by their caregivers. Wandering behavior in dementia patients can result in accidents as well as increased stress for caregivers who must continually monitor their loved ones. We gathered insights from prior research and carer experiences through an exhaustive literature review to inform the creation of our application.

The application's key capabilities include live location observation through the VT03D portable device, the ability to set and change safe zones, and real-time notifications to caregivers when a patient departs from these safe zones. The use of Google Maps API enables precise mapping and tracking, while the position prediction mechanism, powered by a Decision Tree algorithm with a Random Forest component, produces an impressive 94.16% accuracy rate. This name-based location tracking method provides caregivers with a useful tool for anticipating a patient's movements, improving their ability to provide timely aid and support.

One of the research's key benefits is the application's practical implementation utilizing React-Native and Firebase, which makes it accessible and user-friendly. Caregivers have access to historical movement records, playbacks, and real-time location updates, giving them a comprehensive picture of their loved one's activities and movements over time.

Furthermore, the application provides an important degree of security and assurance. In an emergency, such as a device breakdown or a dead battery, the location prediction system is important for quickly locating the patient. This feature considerably decreases caregivers' stress and anxiety since they know they have a dependable system in place to assist them during crucial periods.

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6. APPENDICES

6.1 Gantt Chart

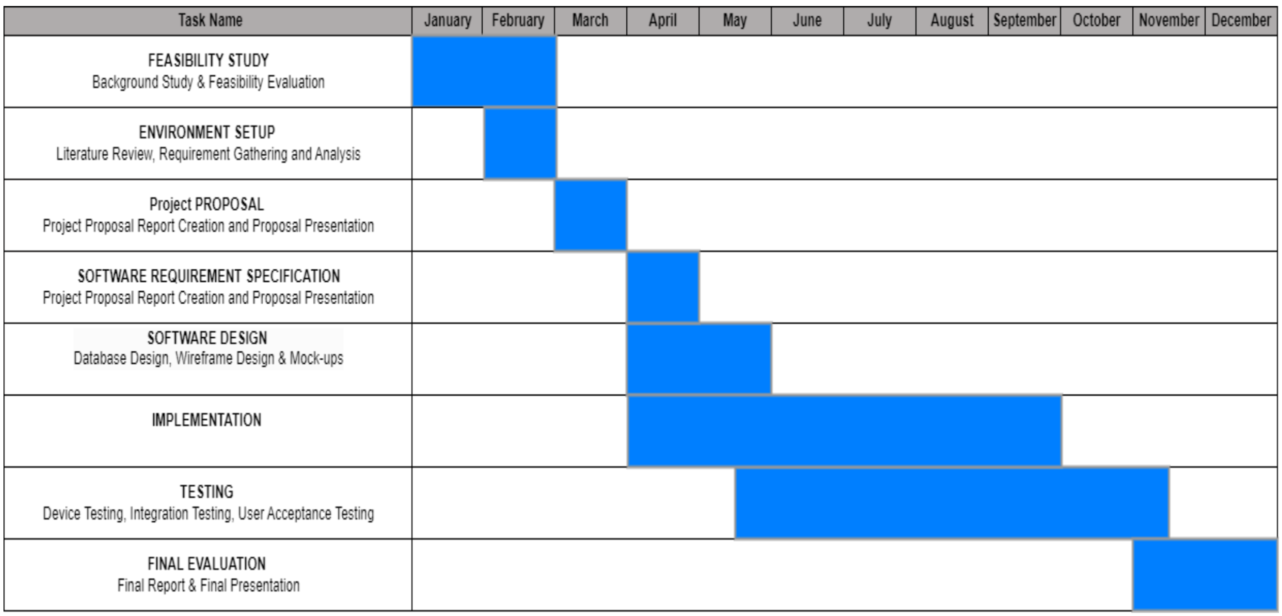


Figure 6. 1: Gantt chart

6.2 Work Breakdown Structure (WBS)

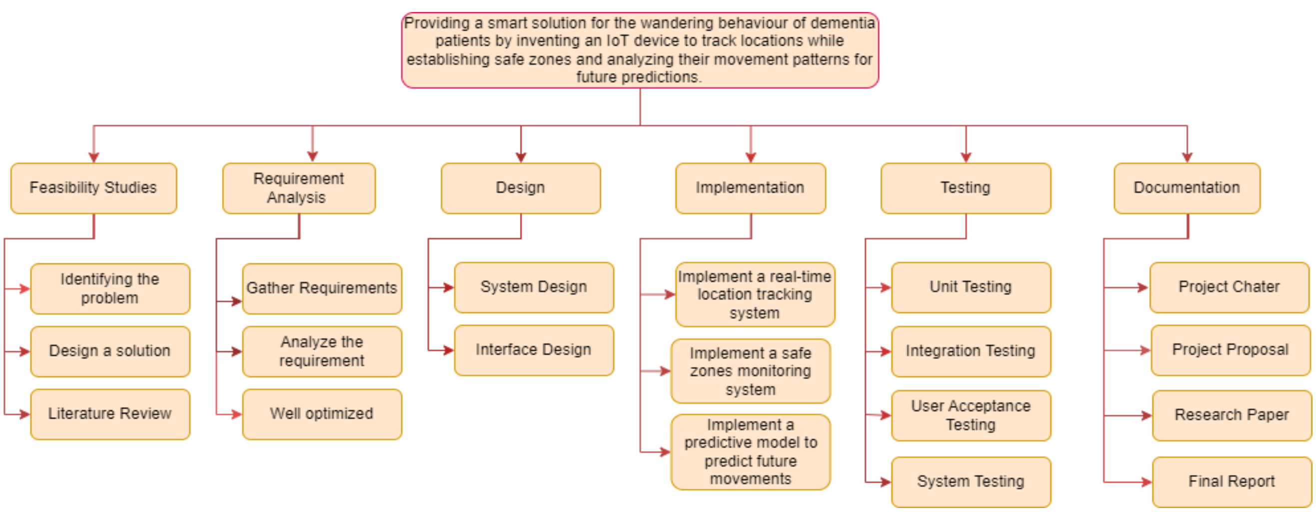


Figure 6. 2: Work Breakdown Structure (WBS)

6.3 Online Survey

Survey conducted in order to get details on developing an IoT device for dementia patients.

Dear Respondent,
I'm a Final year student from the department of computer science and software engineering, faculty of computing , SLIIT

I'm researching about the wandering behaviour of dementia patients and its impact on caregivers lives in order to provide technical solutions to benefit both parties. This survey is conducted to gather some data required to proceed with the research.

epunudantha777@gmail.com (not shared) Switch accounts

*Required

Have you heard about Dementia ? *

- ○ Yes
- ○ No

How much do you know about the disease ?

- ○ I have never heard about it.

How much do you know about the disease ?

- I have never heard about it.
- I have only heard about it. Don't know much.
- I have some knowledge about the disease.
- I have studied/currently studying it.

Have you ever associated with a dementia patient ? *

- Yes
- No

If the answer is "Yes", which age gap the patient belongs to ?

- Younger than 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- Older than 75

As the caregiver, are you experiencing wandering as a habit of the diseased person ? *

- ○ Yes
- ○ No

How often does the person wander ? *

- ☐ Not at all
- ☐ Rarely
- ☐ Once a month
- ☐ Once a week
- ☐ Daily
- ☐ Multiple times a day
- ☐ Else

If the answer is "Else", please provide your answer ?

Your answer

Has the patient under your supervision experienced any fatal injuries / accidents *

Has the patient under your supervision experienced any fatal injuries/ accidents because of wandering ? *

- ◯ Yes
- ◯ No

If the answer is "Yes", please explain that experience.

Your answer

As the caregiver, you find it hard and stressful to keep up your focus with diseased person all the time ? *

- ◯ Yes
- ◯ No

Out of the followings, what features do you think is most helpful in taking care of a dementia patient to ease our burden as the caregiver ? *

- ☐ Track patient's location via mobile phone.
- ☐ Maintain constant communication with the patient while keep his or her independence.

Out of the followings, what features do you think is most helpful in taking care of a dementia patient to ease our burden as the caregiver ? *

- [ ] Track patient's location via mobile phone.
- [ ] Maintain constant communication with the patient while keep his or her independence.
- [ ] Establish safe zones and and change them according to patients current whereabouts.
- [ ] Get alerts when person moves away from the defined border.
- [ ] Find and analyze the places where patients go frequently.
- [ ] Have no idea about this.

Have you ever seen any applications or tools with above mentioned features ? *

- ○ Yes
- ○ No

What do you think about the accuracy of those existing applications and tools that have been build to aid the people with dementia ? *

- ○ Very much accurate
- ○ Some what accurate

What do you think about the accuracy of those existing applications and tools that have been build to aid the people with dementia ? *

- Very much accurate
- Some what accurate
- Neutral
- Not accurate at all
- Not sure/ Don't know/ Have not used any

What are the flaws you see on those applications/ tools ? *

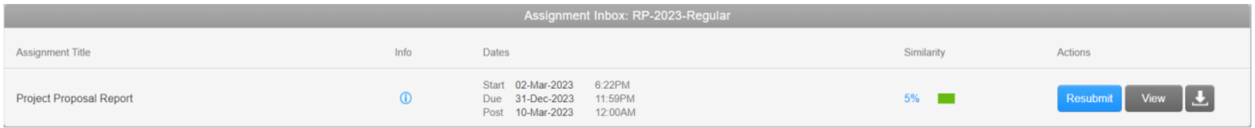
- [ ] Not user friendly for dementia patients
- [ ] Difficult to use
- [ ] Location tracking is not accurate/ Real-time location tracking is not available
- [ ] Alerting systems doesn't work properly
- [ ] Cannot see any flows
- [ ] Cannot/Hard give an opinion

Thank you for participating in this survey and have a nice day !

Submit

Clear form

6.4 Plagiarism Report



Assignment Inbox: RP-2023-Regular

Assignment Title	Info	Dates	Similarity	Actions
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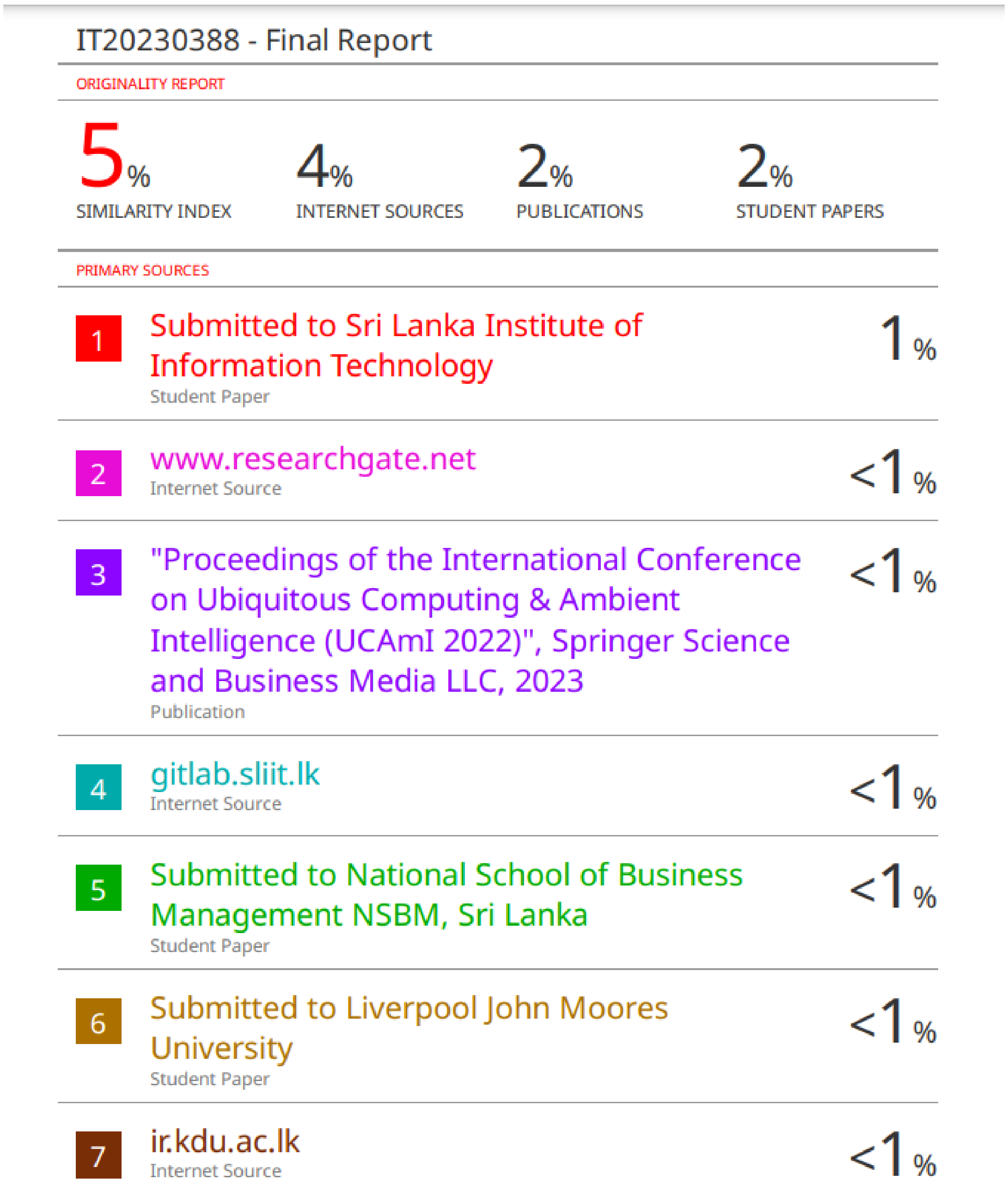

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Figure 6. 3: Plagiarism Report